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THE BUGS THAT EAT PLASTIC, CHEW THROUGH CARBON AND CREATE FOOD FROM THIN AIR

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Bread
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Psychology
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COURAGE IS NOT BEING FEARLESS - CONISTON - MARLOE WATCH COMPANY - DESIGNED IN BRITAIN
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"Each one is a miniature world unto itself, a tiny functioning mechanism, a congeries of minute and mysterious moving parts. Moving parts! And consequently these watches are, in a sense, alive. They have heartbeats".

William Gibson on mechanical watches

BEYOND EXPECTATION

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What are cows communicating when they moo? →p85

FROM THE EDITOR

In labs around the world, there's a tiny revolution taking hold, one that's powered by bacteria. These microbes are fascinating because they're nature's little survivors. Some, known as extremophiles, are found in some of the most hostile environments on Earth, thriving for thousands of years in volcanoes, deep-sea vents and sub-glacial lakes. And others have adapted quickly to flourish in places poisoned by oil, radiation and pollution. Wherever there's a niche, the chances are some type of bacteria has occupied it.

It's this tenacity and ability to adapt in a short period of time that makes them ideal inspiration for helping humans meet some of the biggest challenges of our time: climate change, famine, pollution and disease. If we can harness just a few of their tricks – like pulling electricity from thin air or turning CO_2 into food – then we might be able to make the Earth look very different in the next 100 years. Head to p52 to find out what scientists are discovering in this microscopic world.

If you enjoy that reading that piece, then you really should sign up to our newsletter. It's packed full of the latest mind-blowing discoveries, thought-provoking interviews and science explainers from the team. There's even a free weekly mini-guide to some of the hottest ideas in science right now. I can't recommend it enough. Sign up at **sciencefocus.com/newsletter**

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Daniel Bennett

Daniel Bennett, Editor

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PROF DAVID NUTT

David is a professor of neuropsychopharmacology and founder of drugs advisory charity Drug Science. We speak to him about using psychedelics to treat mental health disorders. →p66

TIMANDRA HARKNESS

Timandra is the presenter of *FutureProofing*, BBC Radio 4's science, technology and society show. This month, she gives us the lowdown on the government's new COVID-19 contact-tracing app. →p33

ABIGAIL BEALL

You don't need a telescope to explore the night sky. In this month's *Astronomy For Beginners* column, our resident stargazer Abigail reveals how to spot the Summer Triangle. →p80

COLIN BARRAS

Bacteria have long been seen as the bad guys. But science writer Colin talks to the researchers who are engineering beneficial bacteria to help tackle our planet's biggest problems. →p52

ON THE BBC THIS MONTH...

The Last Songs Of Gaia

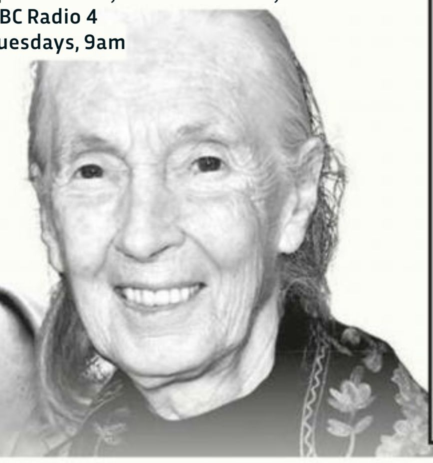
As the climate crisis pushes ecosystems to the brink, animals are silenced. In this four-part radio series, artists, poets and musicians respond to the lost songs of our planet. Episode one begins with birdsong: what would it mean for us if it vanished?

BBC Radio 4
Starts 23 June, 11:30am

Bears About The House

Conservationist Giles Clark takes on the illegal wildlife trade, where the sale of bears for meat, medicine or pets leaves cubs orphaned. Giles also helps to build a new sanctuary in Laos that can give the cubs specialist care.

BBC Two
Starts 13 June



The Life Scientific

This month, Prof Jim Al-Khalili discusses astrophysics with Prof Emma Bunce, and plant and microbial science with Prof Dale Sanders. This month's highlight, though, is the episode with Jane Goodall on 2 June.

BBC Radio 4
Tuesdays, 9am

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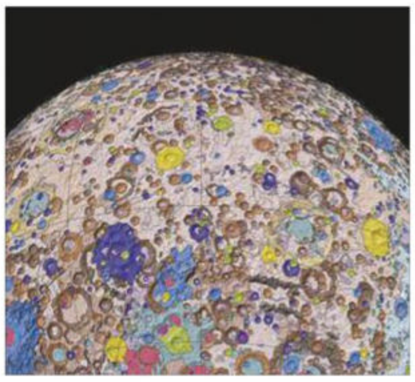

Scientists have used Apollo era maps and new satellite imagery to see the Moon as never before.

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Wild ideas that will shock and astound you

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EYE OPENER

ESO's opticians

ATACAMA DESERT, CHILE

In the Atacama Desert sits one of the world's most advanced optical instruments. The European Southern Observatory's Very Large Telescope (VLT) consists of four units, each housing mirrors 8.2 metres in diameter. While they're protected from the elements, dust particles can damage the mirrors' surfaces and alter the images the VLT captures.

"Here, two engineers are about to clean a mirror by spraying it with carbon dioxide 'snowflakes'," says Gerhard Hüdepohl, an engineer at the VLT. The CO_2 snow is almost -80°C and is used to wipe dust off the reflective surface.

"This is a non-contact way of cleaning a mirror, and can help keep it in good condition for some time." But, every two years, the mirrors must be recoated, says Hüdepohl. "They're dismounted and driven to the base camp, where the old reflective coating is removed with acid. Then a new coating is applied in a so-called 'sputtering process'."

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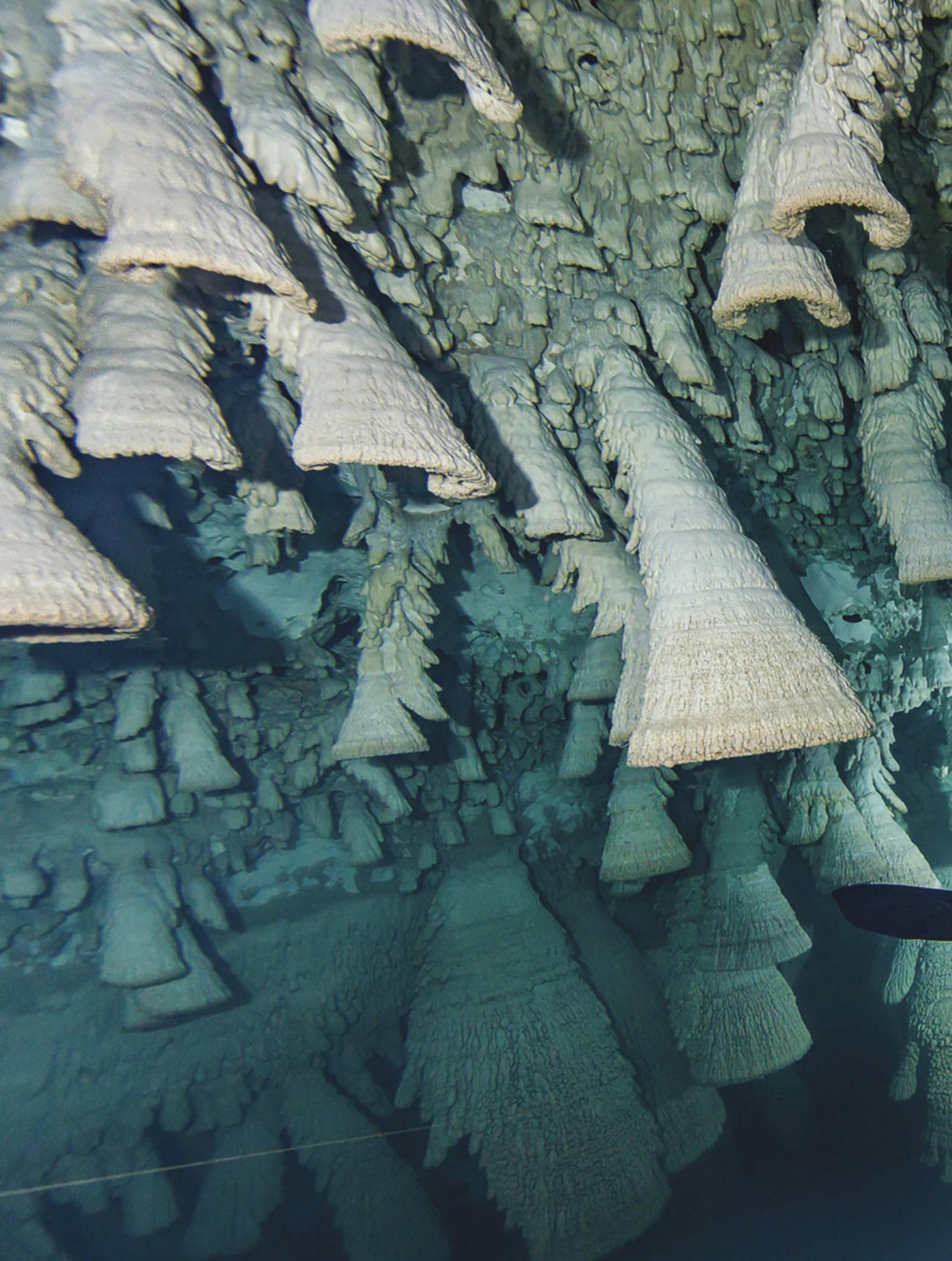

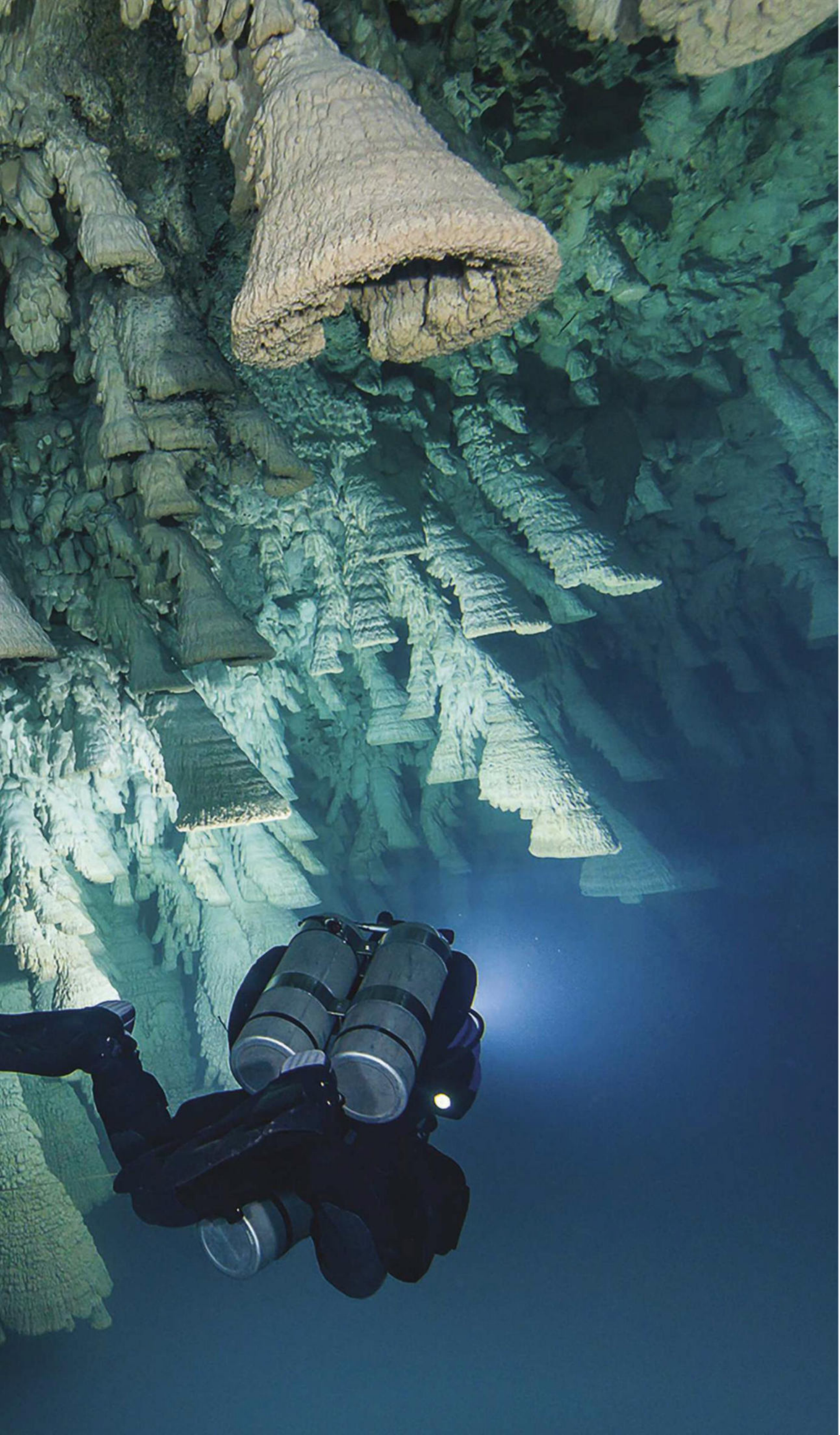

EYE OPENER

Hell's bells

QUINTANA ROO, MEXICO

The mineral calcite comes in several forms. It's the main component of marble and limestone, but here it is in one of its most unusual states. These structures, found in Mexico's El Zapote cenote, were formed from the accumulation of calcite in the water over millennia.

When discovered by divers, they were named 'Hell's Bells'. "Obviously because of their shape," says Dr Simon Ritter, from the Institute of Earth Sciences at Heidelberg University, "but also because of where they are: 40 metres underwater at the start of what's called the turbid layer, where it smells 'hellish', of rotten eggs, due to the dissolved hydrogen sulphide in the water." Divers are able to smell the hydrogen sulphide, as it will de-gas into any available air spaces, like their masks.

Ritter says that the activity of the microbial community in the turbid layer alters the surrounding water's pH, which encourages the formation of calcite.

ALISON PERKINS/INSPIREDTODIVE.COM

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CONVERSATION

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LETTER OF THE MONTH

This cupcake puts the ones we made to shame!

Scrummy science

We tried out your DIY microwave cupcake recipe (February, p85) and had fun with all the measuring and watching the cake rise. We were a little heavy-handed on the chocolate chips though...

The chemistry explanation was understandable, even for a five-year-old. Keep up the good work!

Krystyna Rodriguez, *via email*

Glad you enjoyed our edible DIY science experiment, Krystyna! Is it even possible to be too heavy-handed when it comes to chocolate chips? I'm not sure!

We've got a bunch of other science experiments on our website for you to try out at home, too. Visit bit.ly/science_is_fun

Amy Barrett, *editorial assistant,* BBC Science Focus

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Zanco Smart Pen** from Menkind. This stylus-sized device packs in a dual camera that can take photos and video, a music player, a voice recorder and a laser pointer. It can connect to your phone via Bluetooth, so you can make calls from it too. **menkind.co.uk**

WORTH £69

Think of the bees

The plastic-eating caterpillars in your April issue (p82) are born in beehives. They love honeycomb, yes? Well, our poor old native bees are already under attack from evil killer mites, and foreign murder hornets! Won't releasing these caterpillars into the environment be the final nail in the coffin for our native bees?

Gary S, *North Wales*

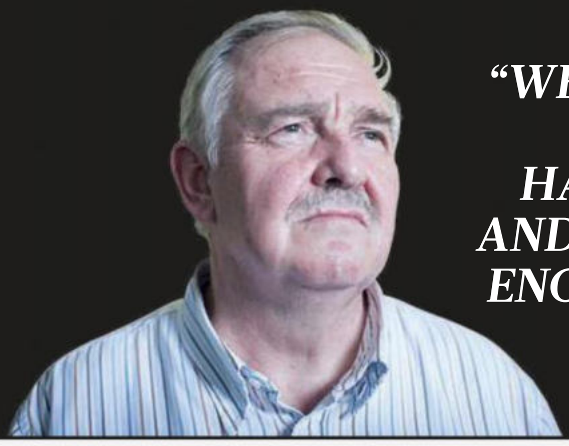
The caterpillar larvae of the greater wax moth are pests of bees. They do not directly harm the bees, but they feed on the pollen and comb, and can cause honey to leak out of hives. Most scientists would agree that releasing the larvae into the wild to help with the plastic pollution crises is a bad idea. What we and other labs are more likely trying to do is determine the products and by-products created by the caterpillar and its gut bacteria that allow for such quick degradation of these plastics. Once we figure these out, we can develop tools to combat plastic pollution!

Bryan Cassone, *associate professor of biology, Brandon University, Manitoba*

Calories vs carbon

The 'carbon cost' of three different daily menus are interesting (April, p63), but a nutritionist

Wax moth caterpillars eat honeycomb, but can scoff plastic too



> “WE’RE HOPING THAT PSYCHEDELICS CAN FRAGMENT THAT ONGOING, HABITUAL PROCESS OF BEHAVIOUR AND THINKING, AND FREE PEOPLE UP ENOUGH SO THEY CAN ESCAPE FROM THE ADDICTIONS”
>
> PROF DAVID NUTT, p66

might have doubts. The calorie count of each menu is very different – I doubt whether the ‘low footprint’ diet would meet the 2,000 calories per day that an active adult needs.

Consequently, the carbon footprint data is effectively worthless. The only way to get a proper comparison is to have three separate menus, all of which meet exactly the same dietary requirements as considered nutritionally healthy, and exactly the same calorie count. Such data would then be useful for me to make carbon footprint decisions.
Paul Jeffels, *Derby*

The short answer to this question is, you are correct. The daily menus weren’t really drawn up with nutritional requirements in mind; they were more of a guide to the carbon footprints associated with familiar meals or food options. The good news is that the online algorithm Dr Graham Horgan and his colleagues built (which is the source of the carbon footprint information in the daily menus we printed in the magazine) does aim to suggest food options that, over the course of a week, will offer a nutritionally balanced diet with a low carbon footprint. It is free to access here: muncher.aws.bioss.ac.uk
Colin Barras, *science writer*

Building Atlantis

You state that Lego can survive in a marine environment for 1,300 years (April, p86). Why, then, are we not building underwater Lego cities? Think of all the global problems we could solve! Even children could help with the construction of buildings (on land, of course) which could then be lowered to the seabed…
Rusty Broadspear, *via email*

Back in 2012, the Open University found that Lego is surprisingly strong – a single brick can support the weight of 375,000 other bricks before it fails. Ultimately, though, Lego is far too expensive to be used as a large-scale building material. So while we’d love an underwater Lego house, it’s unlikely we’ll be living in one any time soon…
Alice Lipscombe-Southwell, *managing editor,* BBC Science Focus

No underwater Lego houses for us

MP3 for me

In April (p38), we asked whether the MP3’s days are numbered. Here’s what you said…

Playing an MP3 at 320kbps still sounds great on the average system, so is satisfactory (for me anyway). Not everyone can afford a super pricey setup. Having lived in the vinyl and cassette era, I appreciate the maxed-out MP3.
SH, *via Flipboard*

For hi-fi enthusiasts and audiophiles, MP3 was always a non-starter.
J, *via Flipboard*

MP3 isn’t going anywhere. It’s the only format currently available that’s truly universal and can be used on any platform. Having been around for two decades, despite there being a plethora of alternatives, is a testament to the format’s versatility, not a sign of weakness.
Mark D McKean, *via Flipboard*

KRYSTYNA RODRIGUEZ, SHUTTERSTOCK, ALAMY

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GIVE ME SOME SPACE

WONDERS OF THE UNIVERSE

WHAT IS DARK MATTER?
IS THERE ALIEN LIFE?
HOW DID IT ALL BEGIN?
HOW HUBBLE'S NEXT PHASE WILL TACKLE THE BIG QUESTIONS

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Will herd immunity stop the virus?
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BLIND MICE
New technique restores vision in rodents **p15**

LOVE STINK
Lemurs produce fruity perfume to attract mates **p16**

HELLO, SUNSHINE
Images from NASA reveal the Sun as never before **p17**

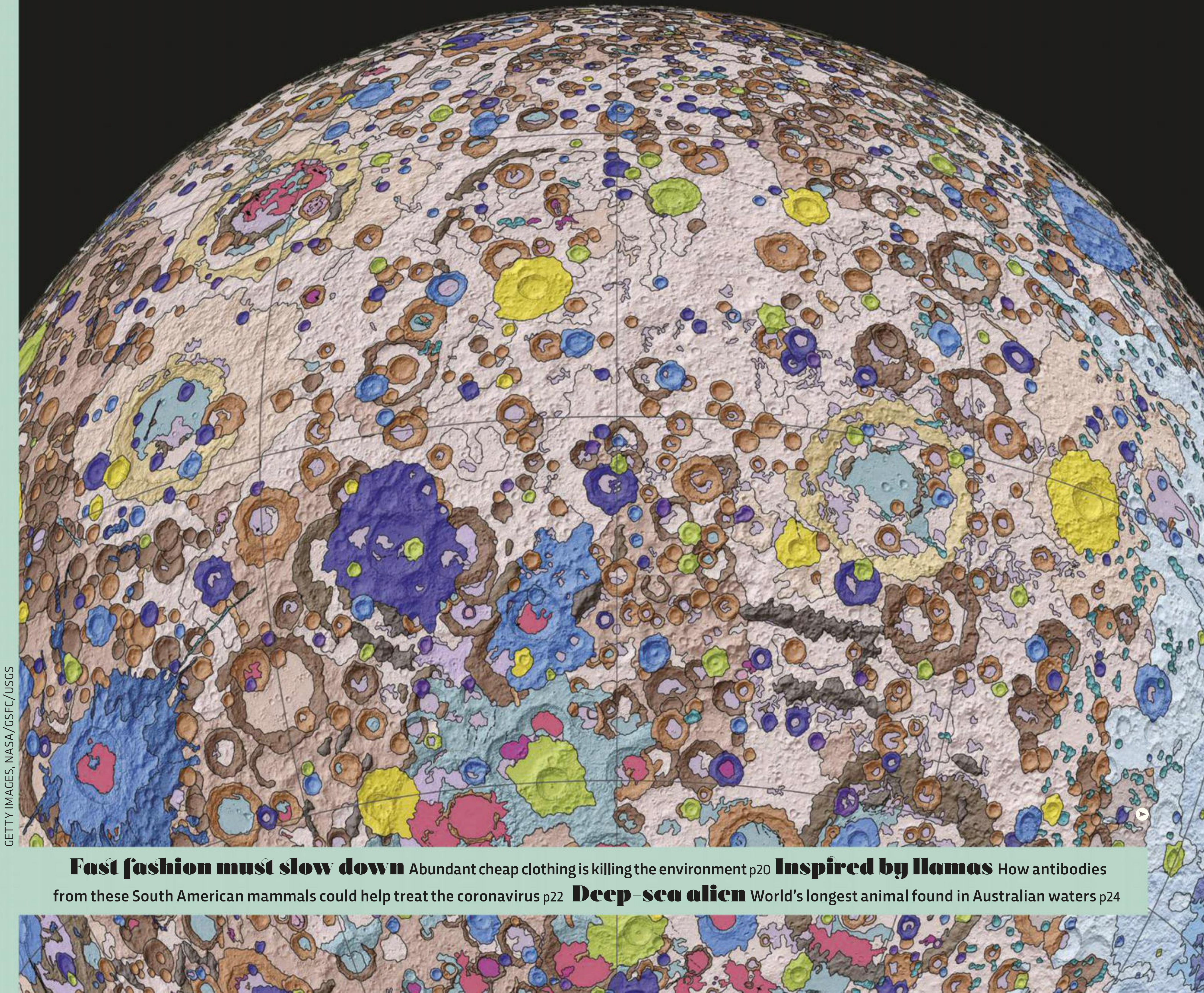
COVID CANINES
Our doggy chums could help sniff out COVID-19 **p19**

DISCOVERIES

SPACE

ENTIRE SURFACE OF THE MOON MAPPED FOR THE FIRST TIME

Decades-long project combines data from Apollo-era maps and information from recent satellite missions



GETTY IMAGES, NASA/GSFC/USGS

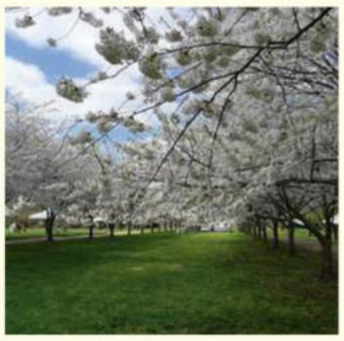
Fast fashion must slow down Abundant cheap clothing is killing the environment p20 **Inspired by llamas** How antibodies from these South American mammals could help treat the coronavirus p22 **Deep-sea alien** World's longest animal found in Australian waters p24

News in brief

GREENER CITIES LEAD TO FEWER DEATHS AND SAVE MONEY TOO

More green space is linked to fewer premature deaths, according to an analysis carried out at the Barcelona Institute for Global Health.

Using the city of Philadelphia as a model, researchers have estimated that if 30 per cent of the area were covered with trees, it could prevent over 400 deaths annually and have an economic benefit of nearly $4bn each year. Extra green space improves mental health, reduces stress and increases opportunities for exercise. "What's more, green spaces increase biodiversity and reduce the impact of climate change, making our cities more sustainable and more liveable," said study coordinator Mark Nieuwenhuijsen.



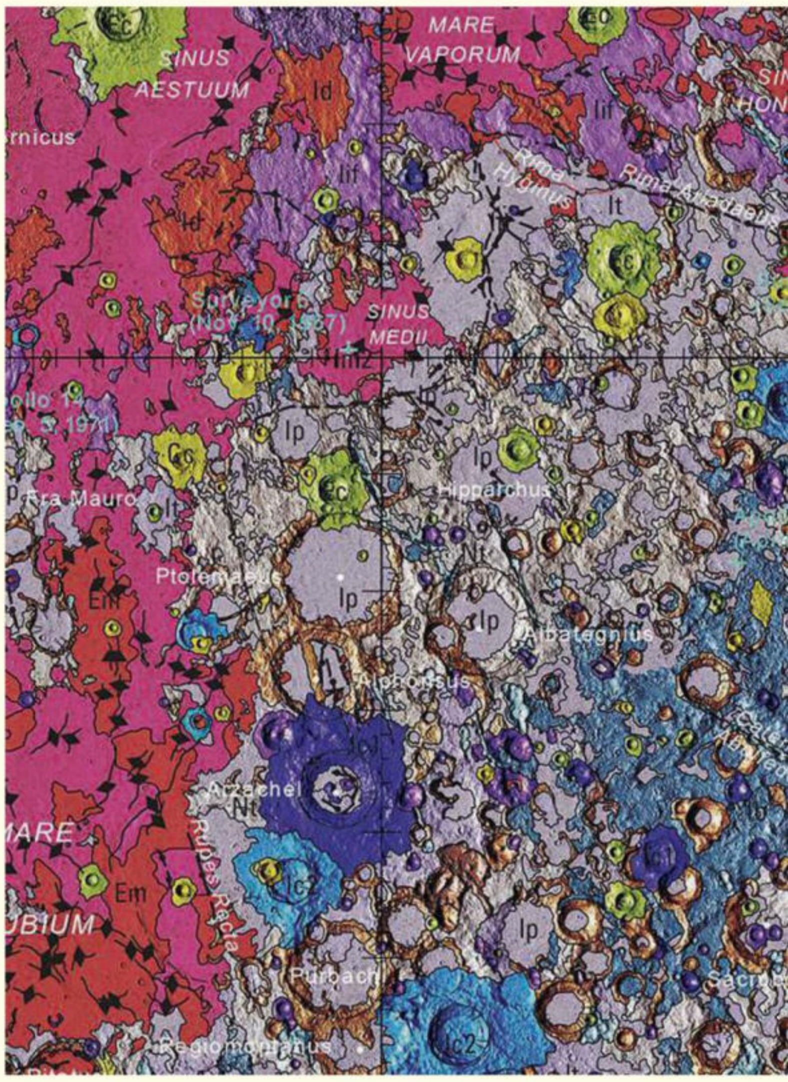
These colourful maps showing the craggy surface of the Moon in exhaustive detail were put together following a mammoth collaborative effort by researchers from the US Geological Survey (USGS), NASA and the Lunar Planetary Institute. It's the first time the entire lunar surface has been completely mapped and uniformly classified by scientists.

The lunar map, dubbed the 'Unified Geologic Map of the Moon', will now serve as the definitive blueprint of the Moon's surface geology for all future human missions. It will also be an invaluable tool for scientists studying the 4.5-billion-year history of Earth's nearest neighbour. The digital map is available online now at **bit.ly/moon-map** and shows the Moon's geology in minute detail on a 1:5,000,000 scale.

"People have always been fascinated by the Moon and when we might return," said current USGS director and former NASA astronaut Jim Reilly. "So it's wonderful to see USGS create a resource that can help NASA with their planning for future missions."

To create the new digital map, the team used information gathered from six Apollo-era regional maps along with updated information from recent satellite missions to the Moon. Data for the Moon's equatorial region came from observations collected by the Terrain Camera on the recent SELENE (Selenological and Engineering Explorer) mission led by JAXA, the Japan Aerospace Exploration Agency. The north and south poles were put together using data from NASA's Lunar Orbiter Laser Altimeter. The team redrew the existing maps of the lunar surface by merging them with modern data sets, a process that also enabled them to develop a new description of the Moon's rock layers.

"This map is a culmination of a decades-long project," said Corey Fortezzo, USGS geologist. "It provides vital information for new scientific studies by connecting the exploration of specific sites on the Moon with the rest of the lunar surface."



FACTFILE: CREWED MISSIONS TO THE MOON

(x) = WALKED ON THE MOON

APOLLO 11

LAUNCH: 16 Jul 1969
CREW: Neil Armstrong (X); Buzz Aldrin (X); Michael Collins

Apollo 11's crew earned a place in history books when they successfully completed the national goal set by President John F Kennedy eight years prior: to perform the first crewed lunar landing and return back to Earth.

APOLLO 12

LAUNCH: 14 Nov 1969
CREW: Charles Conrad (X); Alan Bean (X); Richard Gordon

The second Apollo crew built on the work of the first. In addition to continuing Apollo's exploration tasks, they deployed experiments and recovered portions of a lander that had been on the Moon for two years.

APOLLO 14

LAUNCH: 31 Jan 1971
CREW: Alan Shepard (X); Edgar Mitchell (X); Stuart Roosa

Apollo 14 was the eighth crewed Apollo mission, and the third to land on the Moon. During their two moonwalks, the crew ran science experiments and collected 58kg of rock and soil.

APOLLO 15

LAUNCH: 26 Jul 1971
CREW: David Scott (X); James Irwin (X); Alfred Worden

This was the first Apollo mission capable of a longer stay time. The crew remained on the Moon's surface for 18 hours and 37 minutes – a new record at the time. It was also the first to use the Lunar Roving Vehicle.

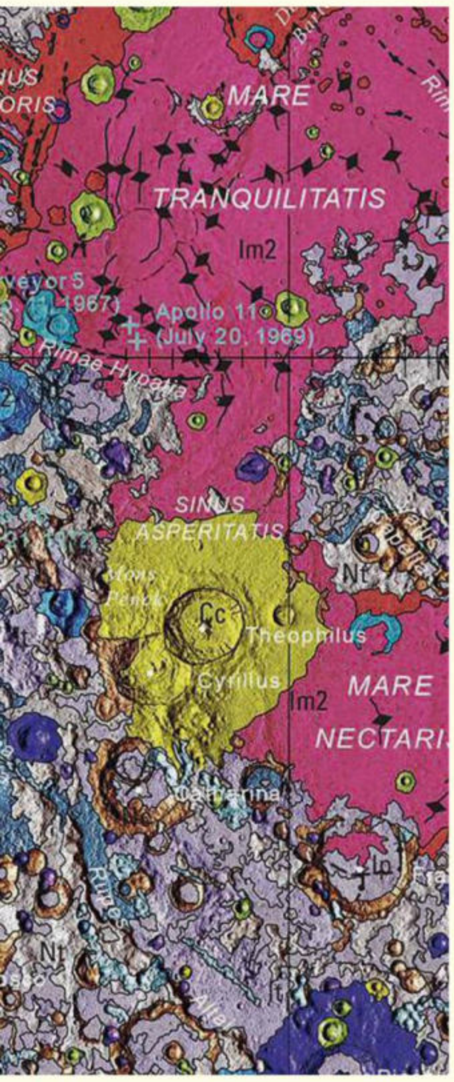
APOLLO 16

LAUNCH: 16 Apr 1972
CREW: John Young (X); Charles Duke (X); Thomas Mattingly

During the Apollo 16 mission, the crew drove more than 25km over three excursions using the Lunar Roving Vehicle, and collected 130kg of samples from the Moon's surface.

A COCKTAIL OF PLANT EXTRACTS MAY HELP TO TAKE THE STING OUT OF A HANGOVER

As anyone who's ever enjoyed too much alcohol can attest, hangovers are no fun: headaches, nausea and fatigue can all last well into the day after. But help may be on the way in the form of a cocktail of plant extracts developed by a team at Johannes Gutenberg University in Germany. The team found that participants who drank a combination of Barbados cherry, prickly pear, ginkgo biloba, willow and ginger root before and immediately after drinking wine or beer reported a drop in headache intensity by 34 per cent, nausea by 42 per cent and restlessness by 41 per cent compared to those who drank a placebo. We'll drink to that.



The different colours provide information about topology, age and chemical features of rocks

APOLLO 17

LAUNCH: **7 Dec 1972**
CREW: **Eugene Cernan (X); Harrison Schmitt (X); Ronald Evans**

Apollo 17 was the last mission in which humans travelled to the Moon. It hosted the first scientist-astronaut to land on the Moon: geologist Harrison Schmitt, who collected important samples of lunar rock.

ALAMY, GETTY IMAGES, NASA/GSFC/USGS, SAI CHAVALA

HEALTH

Rapid new technique restores vision in blind mice

A new technique that could drastically reduce treatment time for reversing sight loss has successfully returned vision in mice, according to a paper published in the journal *Nature* earlier this year.

The treatment would help those with age-related macular degeneration (AMD), which is the leading cause of sight loss in the UK. The problems with vision caused by AMD are due to the loss of photoreceptors – the neurons in the retina that respond to light and are responsible for pupil constriction and dilation. Diabetes and some rare genetic diseases can also cause blindness through the photoreceptor degeneration.

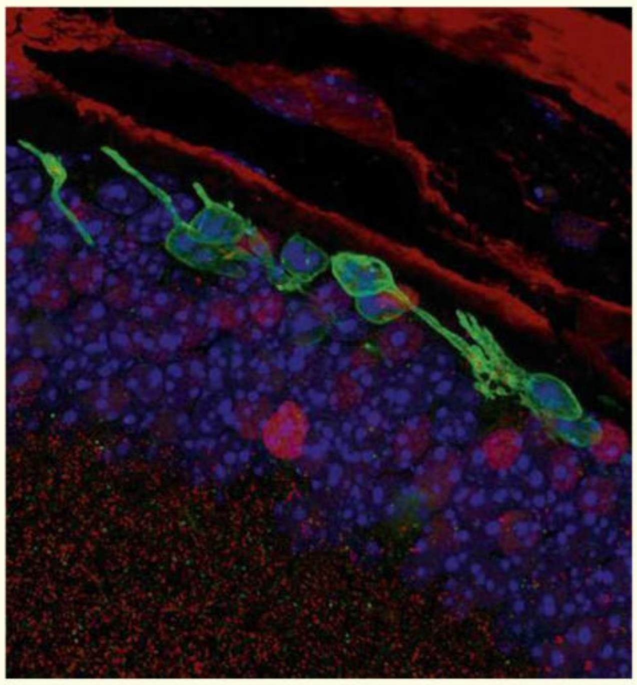
Current treatment for these conditions uses stem cells to replace damaged photoreceptors. Developed in a lab from adult cells, the stem cells are known as 'pluripotent', meaning they can be reprogrammed to become nearly any type of cell or tissue, which can then be transplanted into the patient.

"Stem cell-based strategies are extremely exciting," said Dr Sai Chavala, the study's lead investigator. "However, generating these cells can be cumbersome and time consuming." The process to turn adult cells into stem cells, then into photoreceptors, can take up to six months. The new technique, which was developed by Chavala and the team from the National Eye Institute in Maryland, US, can create replacement cells in just 10 days. The technique, known as direct chemical reprogramming, involves taking skin cells and adding a mix of five small molecule compounds that can 'turn on' genes that are key to the development of the retina. Once the genes are activated, the skin cell becomes something that can mimic photoreceptor cells. These are then transplanted into the patient's eye, which recognises them as new photoreceptor cells and restores lost vision.

The researchers transplanted the cells into blind mice, then tested how their pupils behaved in low light. Of the 14 mice in the study, six had improved pupil response to light after the surgery, showing the surgery worked.

The authors hope that using a patient's own skin to make 'personalised' retinal cells could reduce the risk of transplanted cells being rejected by the body's immune system. While the study used mice, the plan is to run experiments that meet requirements for US Food and Drug Administration (FDA) approval and run the therapy with human participants in the next three years, said Chavala.

Three months after transplantation, the new photoreceptor cells (green) were still alive and had become integrated into the retina



GAMERS

Real-time action strategy computer games can increase the ability to distinguish between important and irrelevant information in real life, according to the University of Electronic Science and Technology of China. More experienced *League Of Legends* players were more efficient in distributing their cognitive resources, the scientists found.

CYCLISTS

Cycle lanes could boost local businesses, particularly in the retail and food sectors, a study from Portland State's Transportation Research and Education Center has found.

Good month

Bad month

THE SLEEP-DEPRIVED

Poor sleep can negatively affect our mood, according to a study at University of L'Aquila. The team found that volunteers were more likely to rate a series of positive and neutral images as unpleasant after five nights of restricted sleep.

MALE DRIVERS

Men pose more risk to other road users than women do, the University of Westminster has found. For cars and vans, the risk posed by male drivers was double that posed by women per kilometre driven.

PEOPLE WITH BROWN FAT BURN MORE CALORIES AFTER COLD EXPOSURE

Brown fat is less common than standard 'white fat', but it's of special interest in the fight against obesity because it burns calories to produce heat when we're cold, unlike white fat which stores calories. Researchers in Vienna used 'positron emission tomography' (PET) scans to identify people with and without brown fat, and found that individuals with brown fat burned on average 20 more kilocalories after short-term cold exposure. "We have to study human brown fat in more detail to see if [it] can protect us against metabolic and cardiovascular disease," said Dr Florian Kiefer at the Medical University of Vienna, who co-authored the research.

ZOOLOGY

Lemurs create a fruity fragrance to attract mates

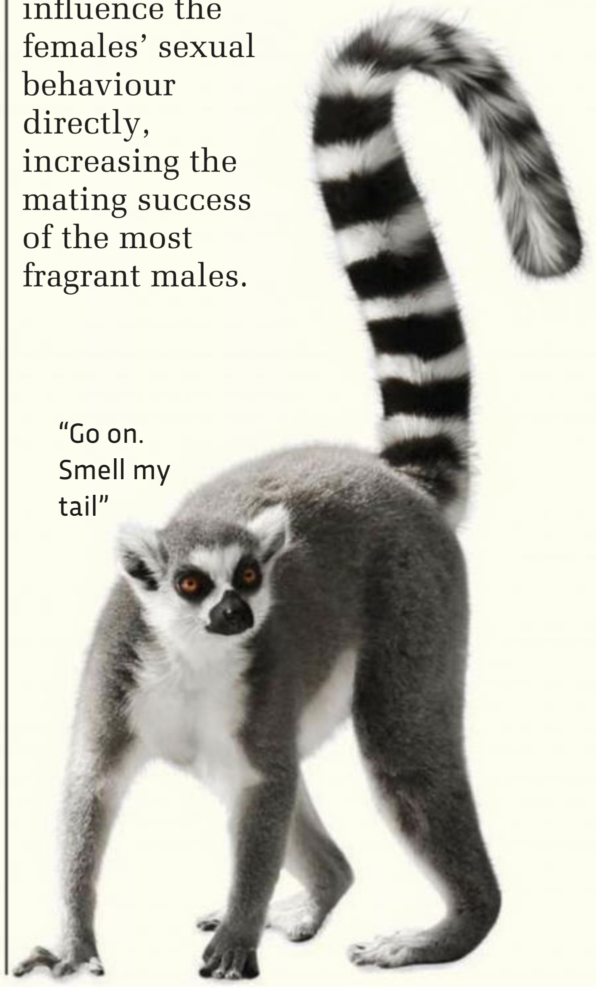
Lemurs, it seems, know that a dab of perfume can make all the difference when wooing a mate. Male ring-tailed lemurs secrete a fruity and floral aroma from scent glands above their wrists, which they rub against their fluffy tails before wafting the sweet scent in front of potential female mates. Now, researchers have identified the ingredients that make this lemur cologne so alluring, and no, it isn't Lynx Africa.

Lemurs are a group of primates that live only on the African island of Madagascar. Both male and female ring-tailed lemurs sport these glands, which secrete a clear liquid that's used to perform scent markings to advertise social rank or reproductive status, or to mark territory. But the males also use it to attract females – a behaviour known as 'stink flirting'.

For this study, a team of researchers monitored frisky lemurs at the Japan Monkey Centre in Aichi and the Research Institute of Evolutionary Biology in Tokyo. When the scientists presented the female lemurs with scents taken from males during the breeding and non-breeding season, the females showed a preference for the fruity perfume from the breeding season, compared to the more bitter-smelling aroma produced in the off-season.

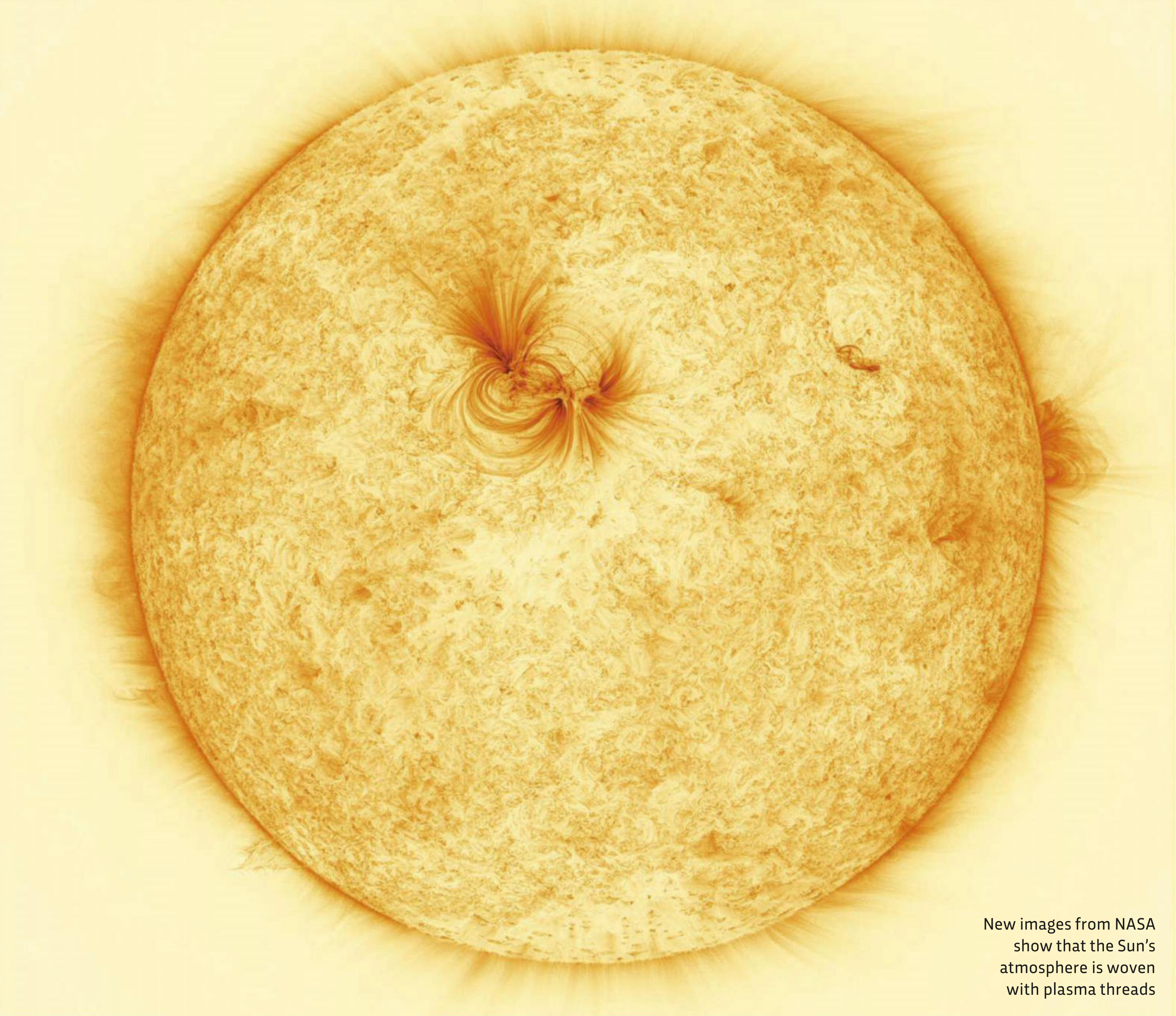
"Females sniff the floral and fruity scent for a few more seconds than the controls and occasionally even lick it," said Prof Kazushige Touhara, lead author and biochemist at the University of Tokyo. "Although this sounds like a very short time, it's enough to … evoke curiosities in the male."

The team used 'gas chromatography–mass spectrometry' to analyse the fruity scent's chemical make-up, finding high levels of three compounds known as 'aldehydes'. The amounts of these compounds increased with male testosterone level, and, when presented with the compounds, female lemurs were only interested in the mixture that contained all three. The results suggest that these aldehydes are lemur sex pheromones – the first to be identified in a primate. Next, the researchers hope to find out whether the compounds influence the females' sexual behaviour directly, increasing the mating success of the most fragrant males.



"Go on. Smell my tail"

CHIGUSA TANAKA/JAPAN MONKEY CENTRE, UCLAN/NASA, SCIENCE PHOTO LIBRARY



New images from NASA show that the Sun's atmosphere is woven with plasma threads

SOLAR SYSTEM

High-resolution image of the Sun shows its atmosphere in unprecedented detail

Detailed images of the Sun produced by a team at the University of Central Lancashire have revealed that its outer layer is riddled with incredibly fine magnetic threads that are filled with extremely hot, million-degree gases.

The ultra-sharp images were taken by NASA's High-Resolution Coronal Imager (or Hi-C for short), a unique astronomical telescope carried into space on a sub-orbital rocket flight. The Hi-C telescope can pick out structures in the Sun's atmosphere as small as 70 kilometres in size, making these the highest resolution images ever taken of the Sun's atmosphere.

Until now, certain parts of the Sun's atmosphere had appeared dark or mostly empty, but the new images have revealed strands that are around 500 kilometres in width, with hot electrified gases, or plasma, flowing inside them. Work will now focus on establishing the exact mechanism that is creating these hot strands and what they can tell us about the eruption of solar flares and solar storms that could affect life on Earth.

"Until now solar astronomers have effectively been viewing our closest star in 'standard definition', whereas the exceptional quality of the data provided by the Hi-C telescope allows us to survey a patch of the Sun in 'ultra-high definition' for the first time," said institutional lead for the Hi-C team Prof Robert Walsh. "This is a fascinating discovery that could better inform our understanding of the flow of energy through the layers of the Sun and eventually down to Earth itself."

RESTORED UK CRANE POPULATION REACHES RECORD HIGH

Cranes were once so common in the British Isles that King Henry III's chefs cooked 115 of them for his Christmas feast in 1251. But a combination of hunting and wetland decline led to their extinction here during the 1600s.

In 1979, a few wild cranes returned to Norfolk and conservation groups began working to support them. In 2010, the Great Crane Project – a partnership between the RSPB, Wildfowl & Wetlands Trust and the Pensthorpe Conservation Trust – was established to improve existing habitats and hand-rear young birds for release.

Figures for 2019 suggest the efforts have boosted the numbers of UK cranes to 56 pairs and that they've managed to raise 26 healthy chicks. The total population is now believed to be over 200 birds – a new record.

They did what?

City rats from US and China undergo genetic analysis

What did they do?

Researchers from Columbia University captured 29 brown rats from Manhattan, New York and compared their DNA to that of nine rats of the same species from Heilongjiang province in China – where the species is thought to have originated.

What did they find?

They found dozens of alterations in the rats' genes related to diet, behaviour and movement. This phenomenon is known as selective sweep, and occurs in humans too.

Why did they do that?

It's already known that rats in different environments display different behaviours (New York rats eat hot dogs and pizza just like their human neighbours, for example). But the team wanted to know if the rats are simply master opportunists capable of making a home anywhere, or if they have made more profound genetic adaptations over the years.

NEUROSCIENCE

Origins of human language stretch back 25 million years

The roots of human language have been traced back to a point 25 million years in our past – 20 million years earlier than the previous estimate.

> "Chimps had been found to have their own version of the human language pathway"

The discovery was made by researchers in the UK, USA and Germany by studying a connection in the brain called the 'arcuate fasciculus' or 'human language pathway'. This bundle of nerve fibres connects regions of the brain that are important for processing language. If this pathway or its connected regions are damaged – through a stroke, for instance, or dementia – it can affect a person's ability to produce or understand speech.

Previously, chimpanzees had been found to have their own version of the human language pathway, suggesting that a precursor to it emerged around five million years ago, when the two species split from a common ancestor. But this new research pushes the date back even further.

The researchers compared brain scans of humans, chimps and rhesus macaque monkeys, and discovered that all three primate species share a segment of the pathway that links the auditory cortex (the part of the brain that processes incoming sounds) with frontal lobe regions, which in humans are important for processing speech and language. This suggests that the pathway emerged 25 million years ago, when humans and macaques last shared a common ancestor, although the researchers say that its origins could stretch back even further.

"It's like finding a new fossil of a long-lost ancestor," said the study's leader Prof Chris Petkov of Newcastle University. "I admit we were astounded to see a similar pathway hiding in plain sight within the auditory system of non-human primates."

Piecing together the origins of humanity's language capability is a tricky task because while bones fossilise, allowing palaeontologists to figure out what our ancestors looked like and how they lived, brains don't. As such, neuroscientists have to use brain scans of living primates and compare these to human scans, in order to gain insights into the minds of ancient primates.

DIABETES ALERT DOG
Medical Detection Dogs

Canines could be trained to detect the scent of COVID-19 in asymptomatic people

EPIDEMIOLOGY

Dogs may join the fight against COVID-19

The UK charity Medical Detection Dogs is looking into whether man's best friend could sniff out COVID-19 and help prevent its spread. To date, the charity has published more than a dozen peer-reviewed research papers supporting the theory that every disease has its own unique odour, and its scientists think that COVID-19 should be no different.

The charity is working on the idea with researchers from the London School of Hygiene and Tropical Medicine, and Durham University – the same team that proved that dogs can be trained to detect malaria. Together, they're preparing to intensively train dogs to help provide rapid, non-invasive diagnoses in suspected carriers. The animals could be ready in as little as six weeks.

Dogs searching for COVID-19 would be trained in the same way as those the charity has already trained to detect cancer, Parkinson's and bacterial infections. The animals would sniff samples in specially designed training rooms and then be encouraged to indicate when they smell COVID-19. Dogs are also able to detect subtle changes in skin temperature, so they could potentially also tell if someone has a fever. Once trained, the dogs could be used to identify people entering the country who are infected with the virus, or be deployed to detect it in other public spaces.

"In principle, we're sure that dogs could detect COVID-19. We're now looking into how we can safely catch the odour of the virus from patients and present it to the dogs," says Dr Claire Guest, CEO and co-founder of Medical Detection Dogs.

"The aim is that dogs will be able to screen anyone, including those who are asymptomatic, and tell us whether they need to be tested. This would be fast, effective and non-invasive, and make sure the limited NHS testing resources are only used where they're really needed."

GETTY IMAGES X2, ALAMY ILLUSTRATION: JOE WALDRON

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**

CAN RAINFALL TRIGGER VOLCANIC ERUPTIONS?

Extreme rainfall could have triggered the 2018 eruption of Hawai'i's Kīlauea volcano, a study by researchers at the University of Miami suggests.

The researchers said that heavy rainfall increases the pressure of groundwater held in porous rock, creating new pathways for magma to get to the surface. This means volcanic activity could be affected by climate change and the impact it has on rainfall. Other scientists are sceptical about the suggested link, but if it's confirmed it could help provide early warnings of volcanic activity, according to Jamie Farquharson, who led the study.

Make way for the new stock: fashion brands now produce almost twice as much clothing as they did 20 years ago

CLIMATE

Fast fashion needs to slow down

Changes to production and consumption practices are needed in order to reduce the fashion industry's impact on the planet

The fashion industry urgently needs to transition to a 'slow' fashion model to reduce its heavy environmental toll, according to researchers at Aalto University, Finland.

The environmental impact of fashion's global supply chain continues to rise, they say in a paper published in the journal *Nature Reviews Earth And Environment*. The industry currently produces over 92 million tonnes of waste and consumes 79 trillion litres of water per year. It causes around 10 per cent of the world's greenhouse gas emissions and is also a high source of chemical pollution.

Developing countries tend to be most vulnerable to the environmental impacts of the industry, since production often occurs there, even though developed countries largely consume the final products.

ELECTRIC BACTERIA COULD PRODUCE GREENER RICE

The impact of rice paddies could be drastically reduced by electricity-conducting bacteria, a team from Aarhus University, Denmark has found.

Water in paddy fields prevents oxygen from getting into the soil, which allows microorganisms that produce lots of methane (a powerful greenhouse gas) to thrive.

In an experiment carried out by Aarhus scientists, rice plants grown in pots with cable bacteria, known as 'living electrical wires', emitted 93 per cent less methane than pots without the bacteria. The cable bacteria recycle sulphur compounds in the soil, which reduces the activity of the microorganisms that produce methane, the study said.

The fashion industry is also projected to grow significantly in the coming decades. Fashion brands are already producing almost twice the amount of clothing they did 20 years ago, while global consumption of textiles is projected to increase by over 60 per cent to 102 million tonnes by 2030, the paper said.

Around 15 years ago, brands would produce four collections a year. These days, many are constantly introducing new collections, according to Dr Kirsi Niinimäki, associate professor in fashion research at Aalto University and lead author of the paper. She argues the whole fashion system has to slow down.

"It's critical that we, as consumers, accept that these cheap garments are not possible if the environmental impacts are really all taken care of," said Niinimäki. "In the future we should produce less. [If] we buy less, there will be less waste."

> "It's critical that we, as consumers, accept that these cheap garments are not possible if the environmental impacts are really all taken care of"

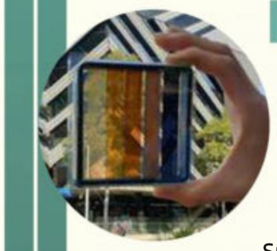
People in the UK buy more clothes per person than any other country in Europe. Last year, a cross-party parliamentary committee in the UK called on the government to add a 1p 'producer responsibility charge' on each item of clothing to pay for better collection and recycling of unwanted garments.

Dr Mark Sumner, a lecturer in sustainability in retail and fashion at the University of Leeds, said that the paper gave a good overview of the material aspects of the industry, but missed the opportunity to highlight efforts by more responsible brands to address these environmental problems.

"There are definitely success stories out there in terms of what industry has done," said Sumner, adding that not enough brands are using that best practice. He also said it's important not to see 'slow' fashion as the only answer. "But I do agree that we need a system-wide approach to understand how fashion works, to then be able to work out how we transition to something more sustainable," he added.

SEA-SAVING SATELLITES

Patches of macroplastic (particles bigger than 5mm) floating in the sea can be detected from space using satellite data from the European Space Agency (ESA), a study at Plymouth Marine Laboratory shows.



SOLAR WINDOWS

Scientists at Monash University in Victoria, Australia, have developed a new kind of semi-transparent solar cell that can be incorporated into window glass, allowing energy to be collected while light still passes through.

INSPIRED

EXPIRED

HURRICANE DAMAGE

Global warming could lead to slower moving hurricanes in the future, which can cause more damage than fast-moving hurricanes, a study carried out at Princeton University has found.

RECKLESS REFORESTATION

Widespread tree planting without careful planning could end up degrading the environment and even increasing emissions, the government's independent natural capital advisors have warned.

IT'S EASY BEING GREEN

TURN A BUCKET INTO A MINI WILDLIFE POND

You can give nature a hand during the coronavirus outbreak by building a wildlife pond in your garden, says the Wildlife Trust.

Frogs, toads and newts will use small bodies of water to breed, says the Royal Horticultural Society, and your pond could also attract insects, such as dragonflies.

Simply bury an old bucket or container in the earth (removing any sharp edges), line the bottom with sand and add a few rocks and some pebbles to allow wildlife to get in and out. Fill it up with pondweed and rainwater, and it's all ready for visiting creatures!

GETTY IMAGES X3, ALAMY, DR JAE CHOUL YU, NASA

Daniel Wrapp biologist

Horizons

Could antibodies found in llamas help us to defeat COVID-19?

Researchers at the McLellan Lab in Austin, Texas, are using llama antibodies to attack 'spike proteins' found on the surface of the SARS-CoV-2 virus

---

WHAT IS A SPIKE PROTEIN AND WHAT IS ITS FUNCTION?

A spike protein is a protein that decorates the surface of a coronavirus. Its jobs is to attach that virus to a host cell by binding to a receptor [on the host cell's surface]. Once it's attached, it fuses the viral membrane with the host cell membrane so that the virus can enter into the host cell and begin the process of replication.

The spike protein is the main machine that the virus uses to enter into our cells. So, without the spike functioning properly on the surface of a virus, the virus is neutralised and is non-infectious.

WHY DID YOU FOCUS ON LLAMAS?

Camelids, which is a family that includes camels, llamas, alpacas and a couple of other animals, produce this special class of small antibodies [proteins produced by the immune system to fight off harmful bacteria and viruses], which are sometimes called nanobodies.

Camelid antibodies are about half the size of the conventional antibodies that you or I would produce, and because of that small size, they have enhanced stability and they're also capable of binding to small crevices or pockets that larger antibodies wouldn't otherwise be able to bind to. [This is why the llama antibodies can bind to the spike proteins on coronaviruses.]

YOUR WORK INITIALLY STARTED BY LOOKING AT ANOTHER CORONAVIRUS, SARS-CoV-1...

We started this in 2016, so well before the current pandemic hit. We immunised a llama against spike proteins from the MERS [Middle East Respiratory Syndrome] coronavirus and the SARS-CoV-1 coronavirus.

We were actually writing up these results in a manuscript to submit when the [current] pandemic broke. So we looked at the genome sequence for SARS-CoV-2 that was released by the Chinese Center for Disease Control and Prevention, and we compared it to the [genetic] sequence of the SARS-CoV-1 spike protein.

We knew, based on our research, that the site the llama antibody bound to was well conserved [similar] between the two viruses. So we took the time to actually test a binding of our antibody to the SARS-CoV-2 spike protein. We found that it bound with fairly high affinity. We then performed some studies in cell culture to show that this antibody prevented infection by SARS-CoV-2.

Also, our lab was the first to produce the atomic structure of the SARS-CoV-2 spike protein, which was published in the journal *Science* in early February. So we had all of these reagents [a substance that acts on another in a chemical reaction] already prepared from our previous

GETTY IMAGES

> **"You could administer antibody treatments to people who are infected, and it would reduce the disease burden"**

Llama antibodies are tiny, which means they are better at binding with viruses, including SARS-CoV-2

experimentation and we had the antibody. It was sort of a no-brainer for us to test the binding.

HAVE YOU STARTED ANY PRE-CLINICAL TRIALS YET?

Yes, we have. We're doing this work in collaboration with some researchers from Ghent University in Belgium. They've begun pre-clinical trials, which are taking place in hamsters.

WHAT SORT OF PROGRESS HAVE THEY MADE?

There are so many difficulties associated with the safety of infecting animals with live viruses. But they're moving as quickly as they can to get it into hamsters. If everything goes well, they'll organise non-human primate trials so that we can eventually move into humans.

WHAT SORT OF TIMEFRAME WOULD WE BE LOOKING AT IN THE BEST-CASE SCENARIO?

We are hoping for about a year until we would have an approved product that could be put into humans.

HOW WOULD WE ADMINISTER THIS ANTIBODY TO A HUMAN PATIENT?

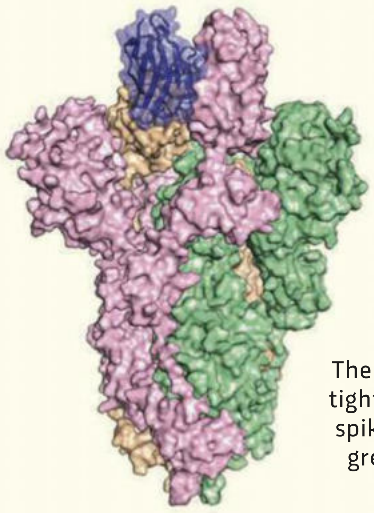
Much like any other conventional antibody treatment, by injection. Really, the nice thing about an antibody treatment as opposed to a vaccine is that you could administer it to people who are already infected, and it would rapidly begin to fight the disease and hopefully reduce the severity of the symptoms.

WHAT'S THE DIFFERENCE BETWEEN AN ANTIBODY TREATMENT AND A VACCINE?

A vaccine has to be administered probably about two months before exposure to the infectious agent in order to be effective. That's because you want to present the human immune system with something that looks like a pathogen [a disease-causing microorganism] so that it can raise its own antibodies and fight off the infection if it's ever presented. Unfortunately, that's sort of useless if you've already been infected. So in that case, you have an antibody treatment for somebody who is already infected to help them get better.

COULD THE TREATMENT ALSO POTENTIALLY BE USED AS PREVENTATIVE MEASURES IN, FOR EXAMPLE, KEY WORKERS?

Yes, I'm glad you brought up essential workers because people like healthcare workers could be administered this drug and then it would reduce or prevent their susceptibility to infection when treating patients.



The antibody (blue) tightly bound to the spike protein (pink, green and orange)

DANIEL WRAPP

Daniel is a PhD candidate in the McLellan Lab at the University of Texas in Austin.

Interviewed by* BBC Science Focus *commissioning editor Jason Goodyer.

Off Ningaloo, Western Australia

MARINE BIOLOGY

World's longest animal discovered in Aussie waters

The 46-metre-long siphonophore was found lurking 625 metres beneath the waves off the Western Australian coastline

A deep-sea expedition led by the Schmidt Ocean Institute has discovered 30 potentially new species of marine creatures, including a siphonophore that's thought to be the longest animal ever observed. It has been estimated to be 46 metres long, nearly six times the length of a Routemaster double-decker bus.

Though they appear to be a single animal, each siphonophore is in fact a colony of organisms that clone themselves thousands of times and join together to form long chains. Like jellyfish, they have stingers that ensnare, paralyse and kill prey.

The discoveries were made using ROV SuBastian, a remotely operated robotic vehicle that's capable of diving to depths of 4.5 kilometres.

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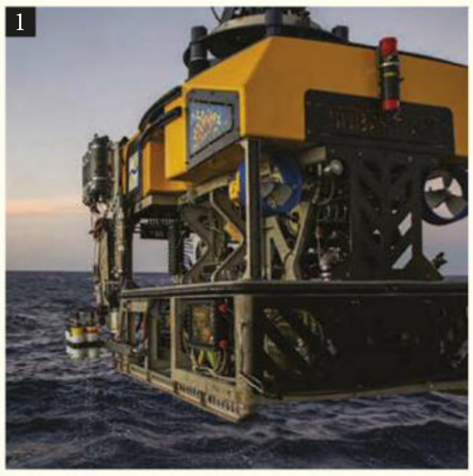

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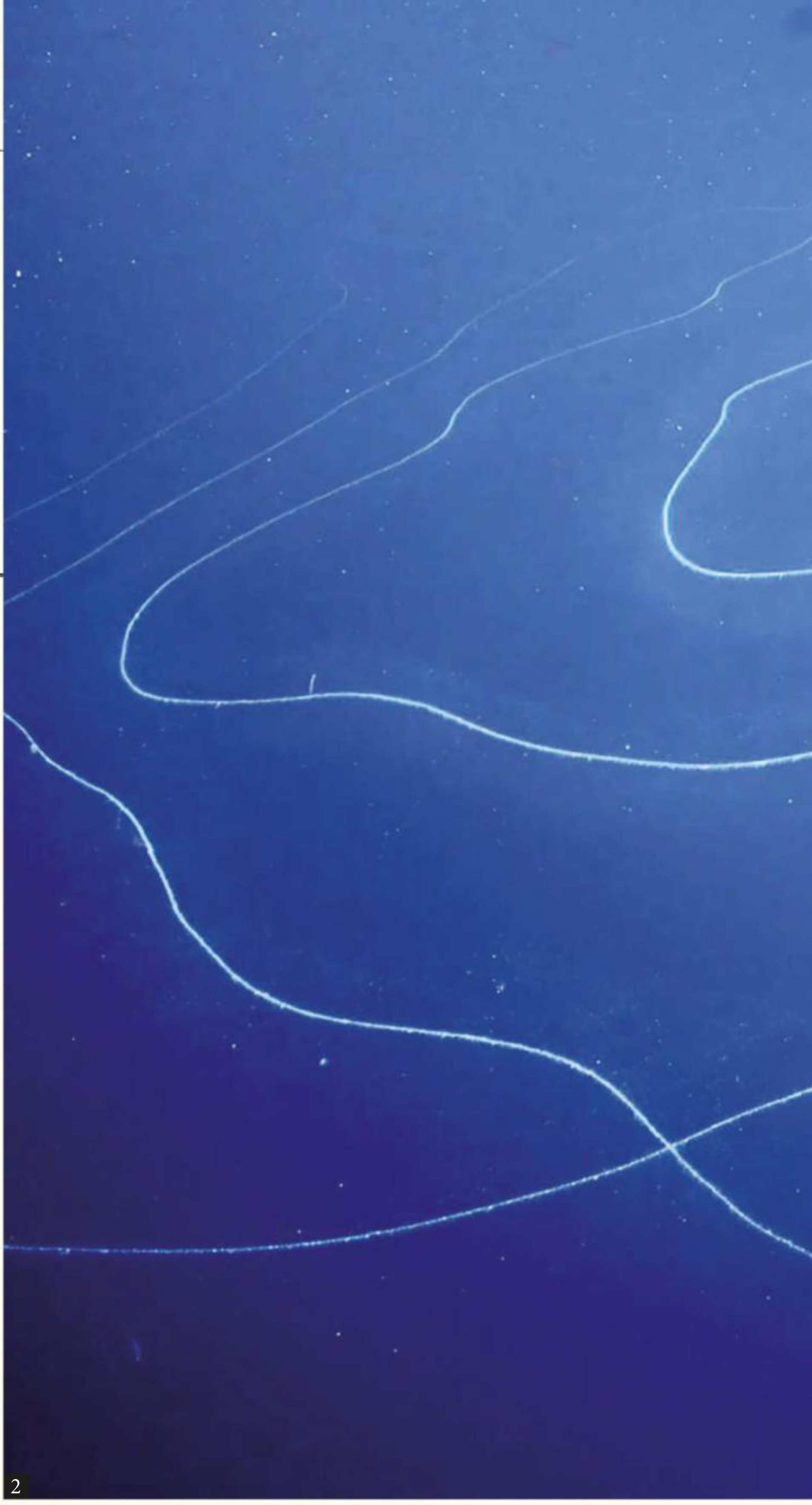

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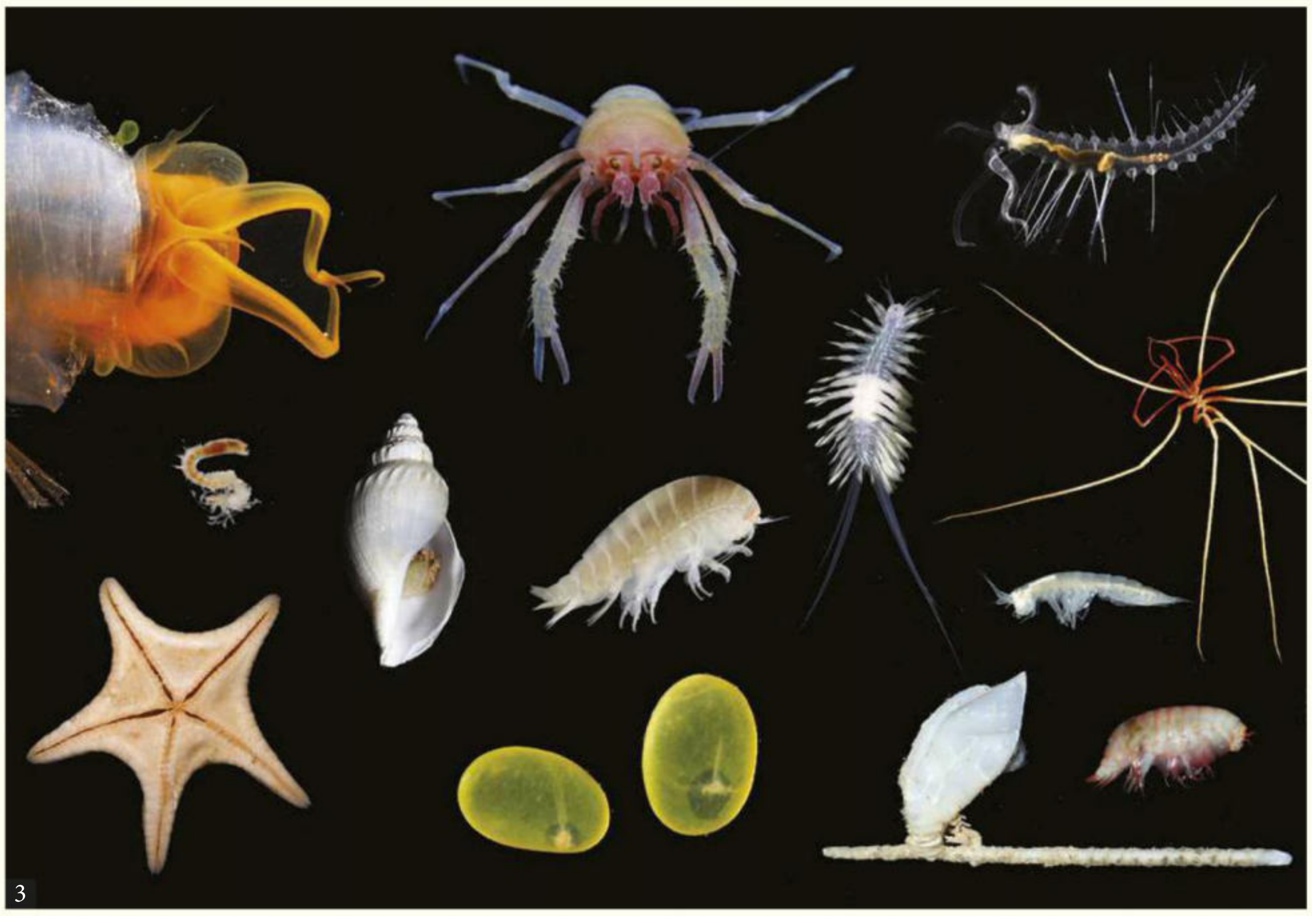

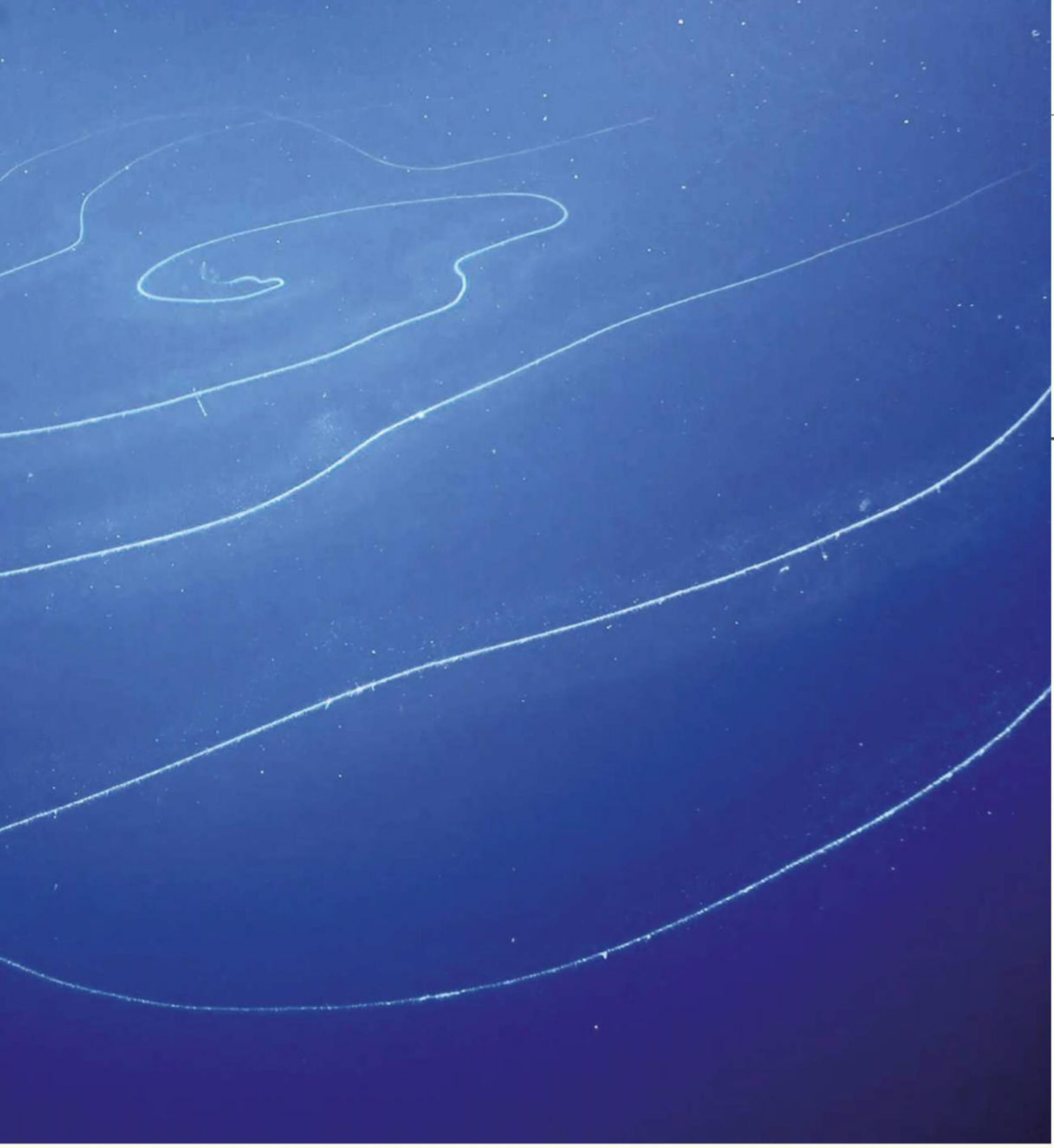

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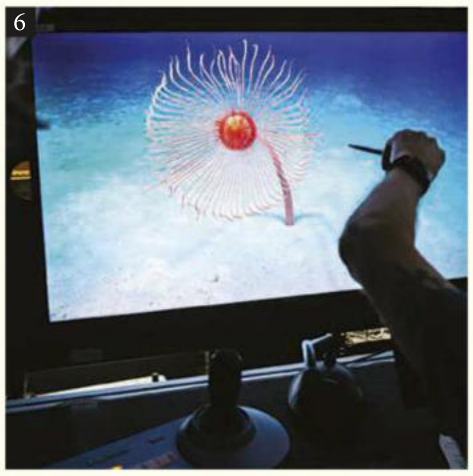

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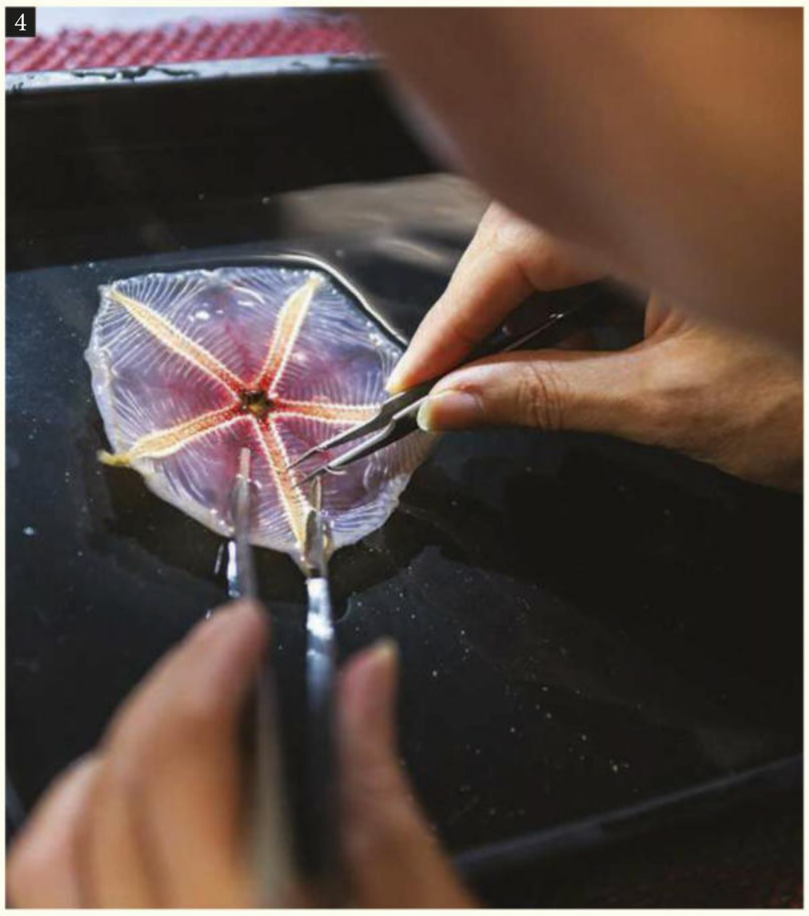

5

1. ROV SuBastian is lifted back on deck after a day of diving

2. The 46m-long siphonopore is thought to be the longest animal ever discovered

3. The expedition found several other species that may be new to science

4. Chief scientist Dr Nerida Wilson takes samples of a hymenaster, a type of deep-sea starfish, for DNA profiling

5. This zoarcid fish was collected from a trap mounted on the lander

6. This rare deep-sea hydroid, a close relative of corals and anemones, was found 2.5km deep in Cape Range Canyon

7. This squat lobster species is distributed all over the globe, but this is the first time one has been found in Western Australia

GREG ROUSE SCRIPPS OCEANOGRAPHY/NERIDA WILSON/FK200308 TEAM X7

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SCIENCE BEHIND THE HEADLINES

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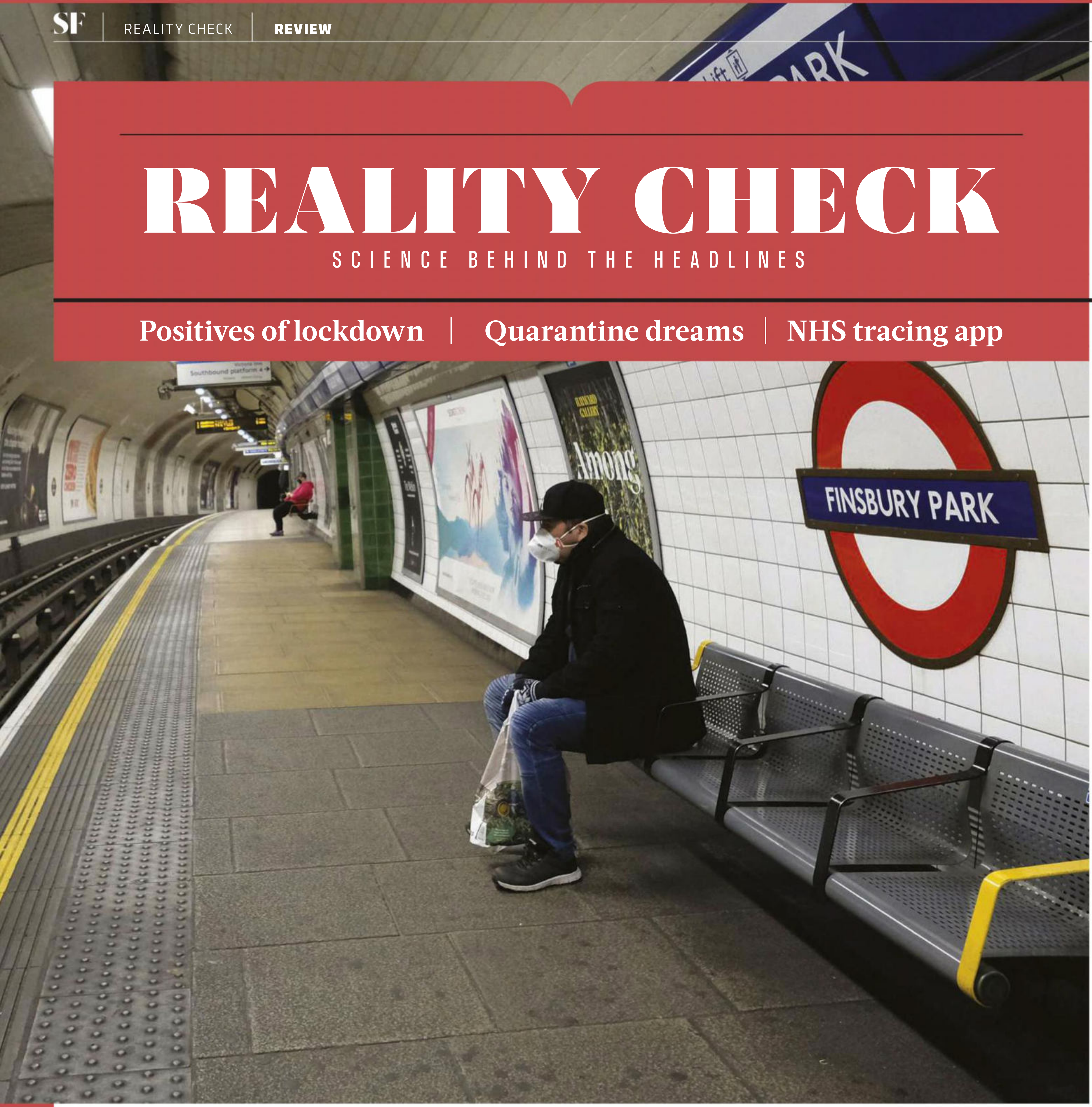


REVIEW

LOCKDOWN AND SOCIAL DISTANCING: ARE THERE ANY POSITIVES?

The coronavirus pandemic has transformed the way we live our lives. But the large number of people staying at home has provided some unexpected benefits for scientists

> **“Every car, train and tube journey contributes to anthropogenic seismic noise. With fewer of us travelling, these noises have decreased”**

BBC *Visit the BBC’s Reality Check website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

The coronavirus pandemic is undoubtedly a tragedy. None of us could have wanted this, and none of us have escaped its impact, between illness, workplace closures and cancelled social events.

The world of science is no exception. Cancer Research UK, for example, expects to lose up to £120m in funding – a quarter of its donated income – this year as a result of charity shop closures.

However, there are some areas of science where lockdown has offered an unexpected opportunity. As the world shut down, researchers in many fields have been suddenly presented with conditions they’d never have been able to create in the lab.

SEISMOLOGY

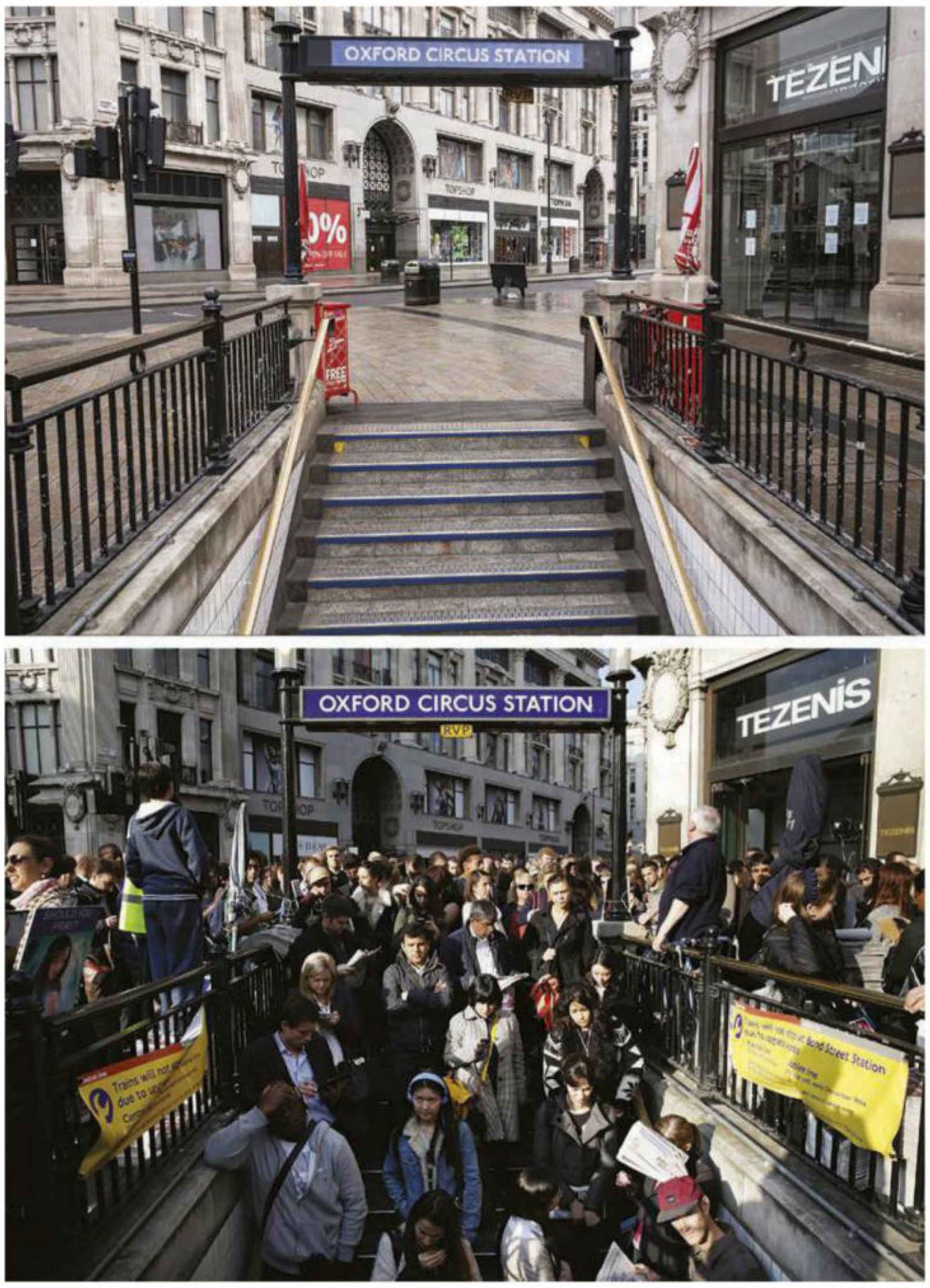
Every car, train and tube journey contributes to ‘anthropogenic’ (human-caused) seismic noise. With fewer of us travelling, these noises have decreased. In fact, seismologist Dr Paula Koelemeijer has recorded a 25 per cent drop in seismic noise at her home in London since lockdown began.

Koelemeijer uses seismic data to image structures inside the Earth. For her, less anthropogenic noise means better quality data. “If the recordings are too noisy due to anthropogenic noise or stormy weather … you might throw away the data and not use it in your analysis,” she says. Likewise when you’re able to image with lower noise levels, you can generally keep more of your data.

A quieter Earth also means that detectors can pick up small quakes that would otherwise go unnoticed. “Picking up smaller events and characterising the background natural seismicity can be useful in locations where we haven’t had any larger earthquakes, because they still tell us what the background levels are,” explains Koelemeijer. “And in city environments, this is generally very unknown because it’s been too noisy to pick up these kinds of signals.”

MARINE SCIENCES

Dr Nathan Merchant is a scientist at the UK’s Centre for Environment, Fisheries and Aquaculture Science (Cefas). He studies the impact of human noise, like shipping and other off-shore activities, on marine life.

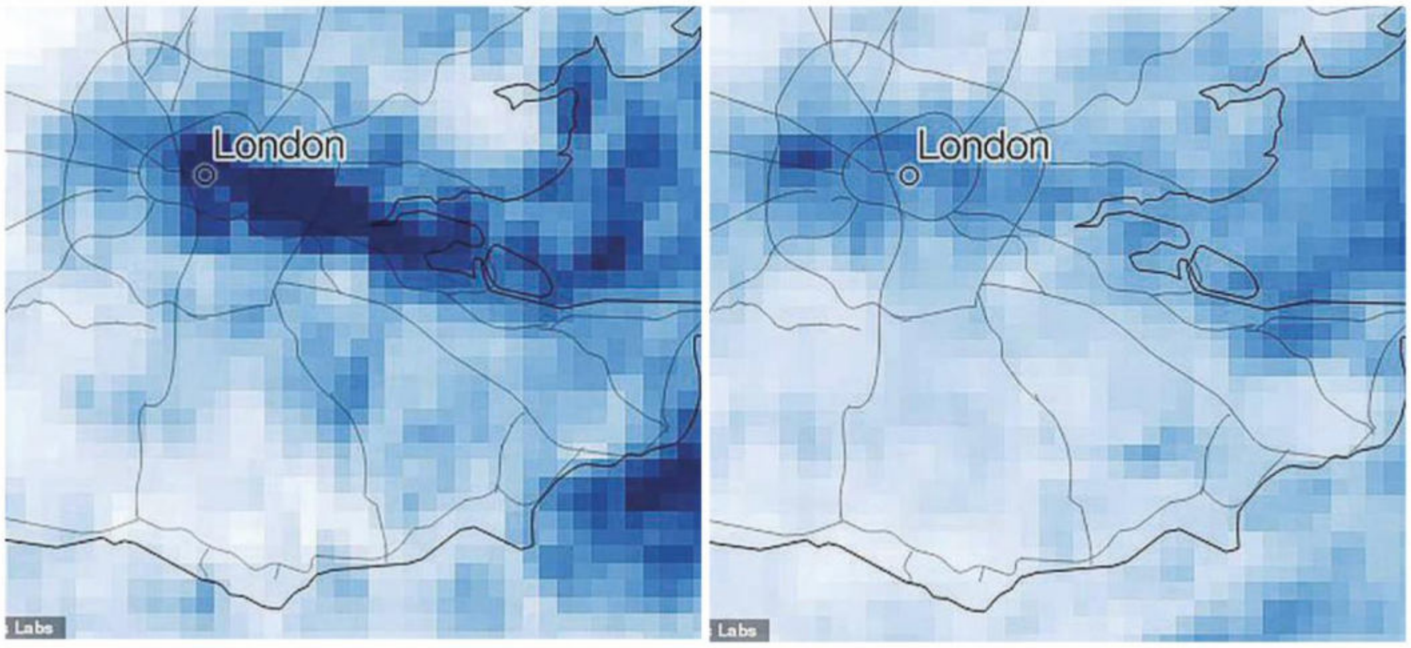


ABOVE Fewer trains, less traffic and reduced numbers of commuters have made London a quieter place during lockdown (top), allowing seismology researchers to detect tiny earthquakes

GETTY IMAGES X2

When restrictions lift and Cefas can collect the data, Merchant expects they’ll be able to see less noise during the lockdown. “We know that a lot of the off-shore activity is lower than it normally is, and so that is what we expect to see,” he says. “But of course, the proof is in the pudding.”

In the short term, quieter oceans are a positive thing. “We know that some marine mammals experience physiological stress related to being exposed to noise,” Merchant says. Whales and dolphins use echolocation, which means they have sensitive hearing. As a result, sudden loud noises can cause haemorrhaging in the inner ear, and prolonged noise from shipping and wind farms can drive them away from their usual safe habitats. In the longer-term, though,



LEFT Satellite imagery comparing pollution over London from March 2019 (far left) to March 2020 (left). The darker areas are regions of higher pollution

the data Cefas gathers will be useful for its role in advising the government on measures to make the oceans quieter permanently. "There will be an economic cost to making ships quieter, to making these off-shore activities quieter. What will be the benefits that we get in return? If we can understand more about those benefits … We're able to advise on much firmer ground in terms of the evidence," he says.

AIR POLLUTION

Stunning satellite pictures from ESA showed air pollution melting away over Wuhan and Italy as lockdown took hold. The same happened in the UK. "There's definitely been some really clear changes in air quality that are obviously linked indirectly to coronavirus," says Dr Mark Broomfield, air quality expert at Ricardo Energy & Environment, an engineering and environmental consultancy.

There are factors beyond traffic that determine how heavy air pollution is, including weather and seasonal changes, but also general day-to-day variation. This means it's hard to tell if air quality on a particular day is better than expected.

"But if we compare, for example, this year to last year or the trend from previous years, you can definitely see reductions in pollution levels," Broomfield explains. "So I'm pretty sure that the change that we're seeing now, at least in large part, is due to changes in activity."

In terms of air quality science, the difficulty isn't the lack of data. "The problem is not so much knowing what to do, it's having the will and the support and the investments needed to do something," Broomfield explains.

That's what Broomfield hopes we'll get out of lockdown: a desire to see our air quality stay this high. "Maybe a lot of the things that we used to think were essential, like commuting to work or flying around the world to go to meetings and that sort of thing, we'll think, well, do we need that?"

That's certainly happening elsewhere in the world. In Milan, 35 kilometres of roads are being converted into cycle paths, and residents of Delhi have been celebrating the clean air since lockdown began.

"[Lockdown] is not the solution," Sunita Narain, director of India's Centre for Science and Environment, told *The Guardian*. "But whatever the new normal is post-COVID-19, we have to make sure we take this breath of fresh air and think about the serious efforts we need to deal with pollution in Delhi."

CITIZEN SCIENCE

Not all science is done by university professors with million-pound equipment. Some of the most valuable data is gathered by interested members of the public. These citizen scientists can collect information from home, whether they're counting insects or measuring rainfall, and build a much wider picture than one research group could alone.

"We're using data from people that have seismometers in their homes," says Dr David Cornwell, a geophysicist at the University of Aberdeen.

Cornwell believes that lockdown is moving scientific collaboration online, which allows researchers like him to connect more with citizen scientists. "That linking of professional projects with citizen science is great," he says. "And what we're hoping is that we can build on it, start some projects, and to inspire some, particularly kids, to do this kind of thing."

If you want to get involved with some citizen seismology, the British Geological Survey has a number of projects you can take part in. If seismology isn't your thing, there's are various projects available via the Natural History Museum, NASA and *BBC Sky At Night* presenter Chris Lintott's Zooniverse.

by **SARA RIGBY**

Sara is the online assistant at BBC Science Focus.

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ANALYSIS

SLEEP IN QUARANTINE: IS THE LOCKDOWN AFFECTING OUR DREAMS?

A YouGov poll has found we're recalling our dreams more than usual. But what, if anything, does it mean?

Nearly one in three adults is remembering more dreams, according to a YouGov poll of 2,477 Americans in April. These aren't just any dreams: Google searches for weird and strange dreams has spiked, and searches for the question 'why am I having weird dreams lately?' has tripled. So is the lockdown affecting our sleep?

There are several stages within one night's sleep. First of all, we get drowsy. Our brain activity begins to lull and we move quickly into light, then deep sleep – these three stages together are what's known as non-rapid eye movement (non-REM) sleep. After around an hour's sleep, we move into rapid eye movement (REM) sleep. Both REM and non-REM sleep is vital for the brain – any disruption to either has been observed to affect mood and memory in particular – and we cycle between the two several times during the course of the night. While we don't yet fully understand exactly what happens in our brains while we sleep, our current best theory is that non-REM sleep is restorative, rejuvenating our neurons, while in REM sleep our brain is focused on consolidating memories.

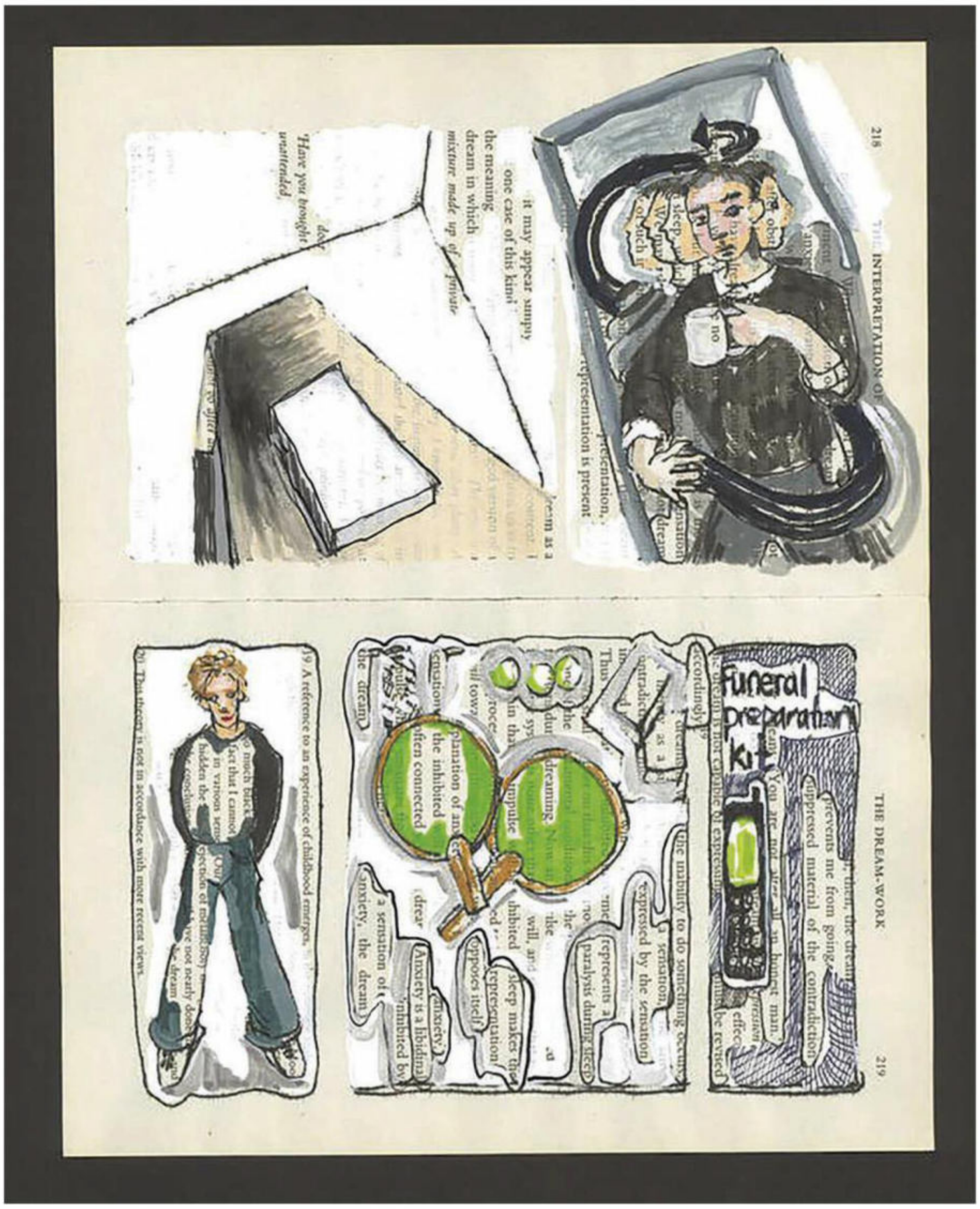
WHY WE DREAM

The leading theory of why we dream is that dreaming is a side effect of our brain sorting through and processing our memories. This is why we tend to associate REM sleep with dreaming – though we do dream in non-REM sleep, studies have found we are less likely to remember these dreams.

"The problem with that theory is that a lot of processing the brain does, it can do without needing to be conscious. It doesn't need to dream to file away memories," says psychologist Prof Mark Blagrove, director of the Sleep Laboratory at Swansea University. "Other theories say we dream as we are altering our levels of emotions. Another is that we're actually doing a virtual reality type of practice for future situations, like we're acting in a safer, simulated environment. Other people say that there's no function to it: we have evolved to have imagination when we we're awake, and that just carries on when we're asleep."

So how has the coronavirus pandemic changed the way we dream?

"We know that people are having more dreams than normal," explains Blagrove. "It seems to be because people are sleeping longer. A lot of people are waking up without alarm clocks, so their final REM sleep period of the night is probably longer than it normally would be." ▶



ABOVE Prof Mark Blagrove is working with an artist to illustrate pictures of people's lockdown dreams. Find out more at **dreamsid.com**

Our morning routines are also more relaxed, which means we probably have more time to stop and think about the dreams we've just awoken from, Blagrove explains. It is not just that we're remembering more of our dreams, though – it seems that people are reporting having more intense dreams, either positive or negative, too.

Experiments at the University of Swansea have shown that we dream of our waking life's emotional experiences more than non-emotional experiences. "Emotions for a lot of people may be higher over this period. There are those who are worried about their health or others' [health], about losing pay or their jobs, or maybe they're doing a dangerous job at the moment." It is these people who are probably having very poor sleep, says Blagrove.

WHY STRESS AFFECTS DREAMS

During the first three weeks of the lockdown period, stress was the nation's primary emotion, a YouGov poll found. It takes longer for us to fall asleep when stressed, as we're ruminating on our worries. "Stress has also been found to make us have more nightmares," says Blagrove, "although these nightmares are often not about the specific stressor occurring – instead, they may have some other theme but carry the same negative emotion from waking life."

However, the 35 per cent of the UK population who are working at home and still being paid may be having blissful sleep. "If they're with people they like being with, they may have more positive dreams," notes Blagrove, putting himself in that category.

Talking to *The New York Times*, Harvard Medical School psychologist Dr Deirdre Barrett suggested one could 'program dreams' by imagining a positive scenario before you go to sleep, or by placing "a photo or other objects related to the topic on your nightstand to view as the last thing before turning off your light."

But Blagrove isn't convinced that simply 'thinking happy thoughts' before bed can change dreams. "Everyone recommends that people reduce their anxieties before sleep. Yes, it's possible that that may impact their dreams, but if you're anxious for the rest of the day, it may well be that there's little you can do just before sleep. Your dreams will be able to pick up on what recent, consuming emotions you have."

The main technique that therapists use for helping people address nightmares involves repeatedly reimagining the nightmare, with small aspects of it changed. This has been shown to reduce bad dreams – but only for nightmares brought on by previous stresses, not existing ones.

"For a lot of people at the moment, the stress they're under is a very current stress. And so it may be, I'm afraid, that the nightmares will still happen. It may be that we need to have an end point to it [the pandemic] for our dreams to get back to normal."

by **AMY BARRETT**

Amy is editorial assistant at BBC Science Focus.

DISCOVER MORE

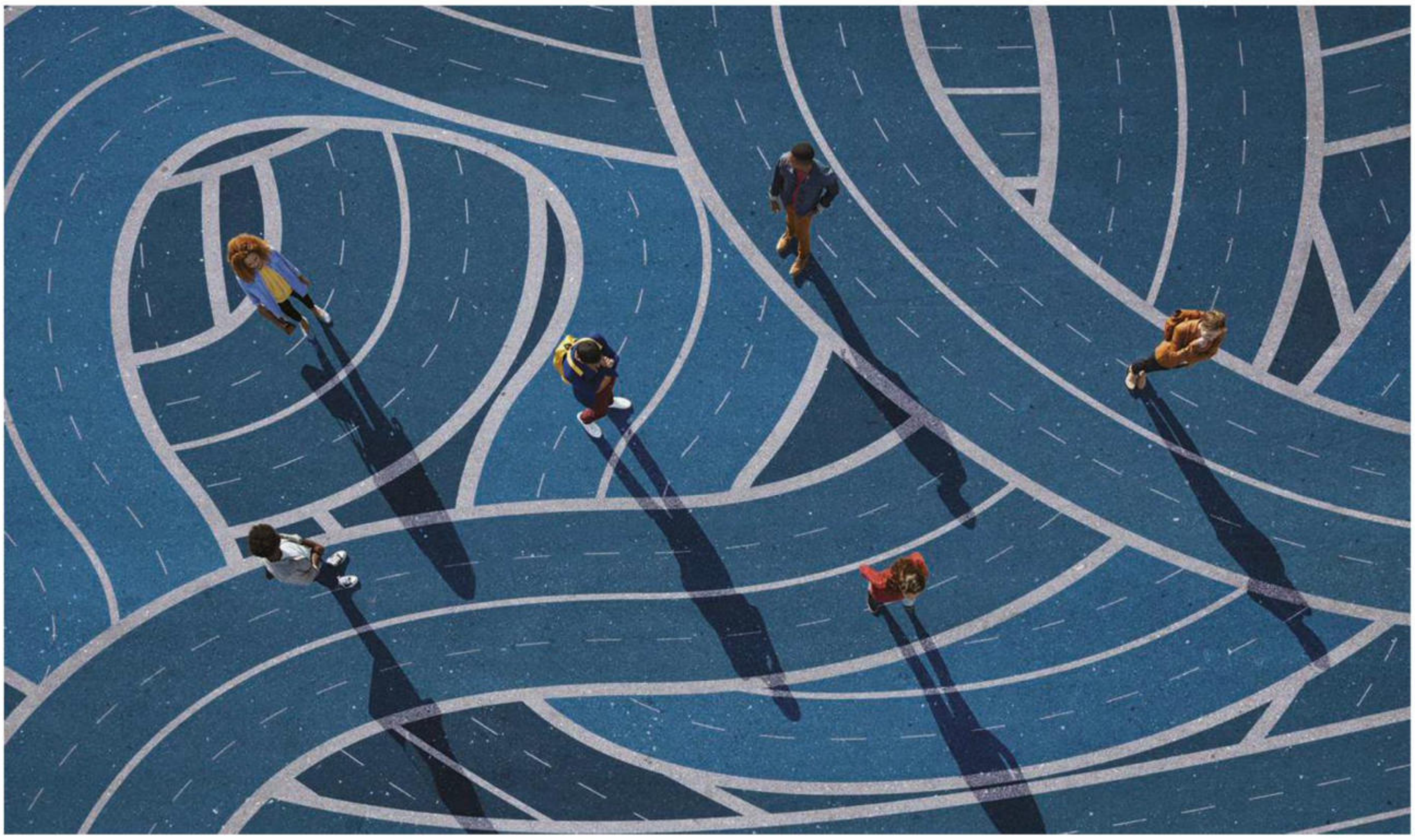
A group of postgraduate students at University College London Psychoanalysis Unit are collecting the details of people's dreams during the coronavirus pandemic for an independent personal project. Share your dreams by going to: ***lockdowndreams.com***

GETTY IMAGES

COMMENT

NHS CONTACT TRACING: WILL IT WORK?

NHSX, the digital branch of the NHS, is trialling an app that will tell you if you have been in contact with anyone who has shown symptoms of COVID-19. But at what cost to privacy?



One big challenge in the fight against COVID-19 is the fact that it is contagious before any symptoms emerge in people who are infected.

Contact tracing can help reduce the spread of the virus, by finding out how many people the patient may have unknowingly infected before they realised they were ill. There are a number of means of doing this. In South Korea and Singapore, for example, contact tracers work with patients to retrace their movements, using information from CCTV footage, mobile phone location data, and even credit card records. Individuals at risk are then contacted and told to self-isolate and get tested.

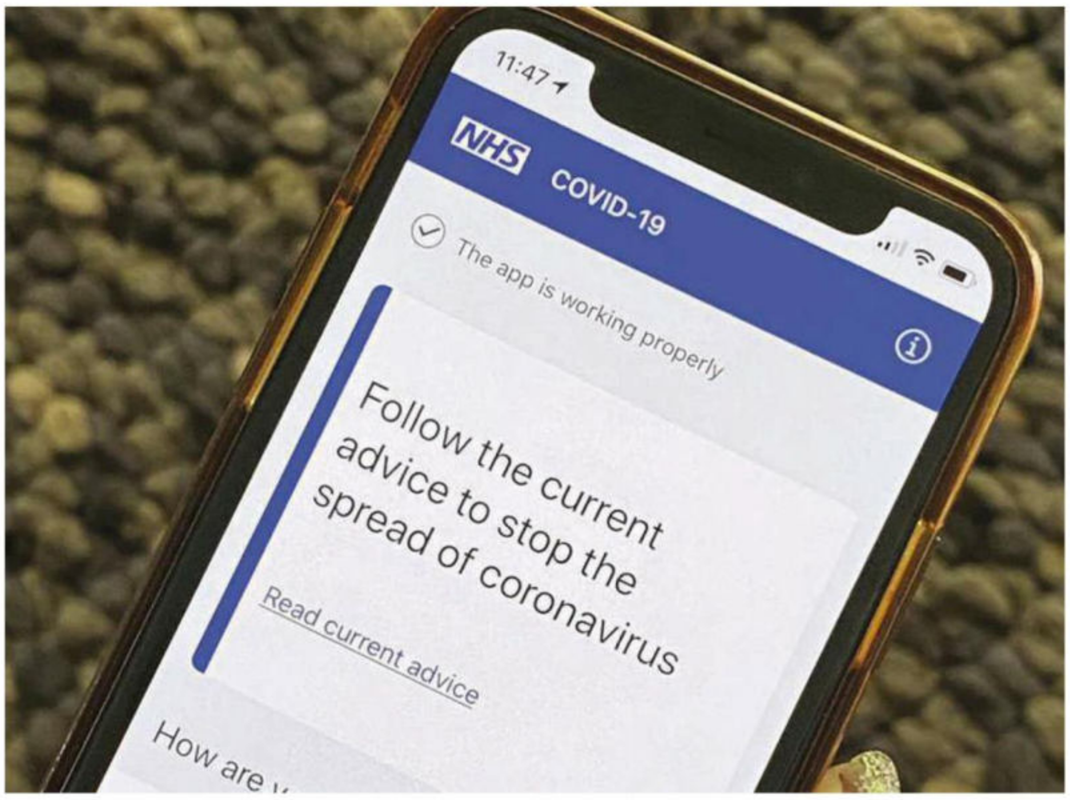
Singapore also launched a *TraceTogether* app that uses proximity to aid with contact tracing. *TraceTogether* doesn't track locations, but instead uses Bluetooth Low Energy to ping anonymous codes directly to nearby phones. If somebody is diagnosed with COVID-19, those signal codes can be used to find devices that were recently within a few metres of that person and warn the owners to get tested.

CONTACT LIST

The NHSX app works in a similar way to *TraceTogether*, using Bluetooth to exchange signal codes between app users. If you develop symptoms and are diagnosed as having COVID-19, you share your recent data by uploading a copy of the codes from your 'sent' folder to the NHSX database. Those codes can then be cross-checked by all the other phones running the app, to see if they have a code from an infectious person's phone in their 'received' folder.

The problem is, Bluetooth makes it easy for other devices to get data from your phone, so Apple and newer Android phones don't allow Bluetooth to run when you're not actively using the relevant app. *TraceTogether* only works if you leave the app running and the phone ▶

“Apple and Google have said that they will only approve contact-tracing apps that follow a specific protocol”



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NHS COVID-19

The app is working properly

Follow the current advice to stop the spread of coronavirus

Read current advice

How are y

ABOVE The NHSX contact-tracing app currently uses an approach that may reveal information about users

unlocked all the time (even in your pocket). This is clearly a privacy problem, as any pickpocket has instant access to everything on your phone.

Apple and Google recently announced imminent changes to their operating systems, designed to make contact-tracing apps work better. The new changes will allow Bluetooth to run in the background, even when the phone is locked or when you’re doing something else, but only to exchange signal codes with nearby phones. But it will only work for contact-tracing apps that have been approved by the two tech giants. If they don’t approve an app, users would still have to leave their phone unlocked all the time to run it.

Apple and Google have said that they will only approve contact-tracing apps that follow a specific protocol, similar to a project called DP-3T (Decentralized Privacy-Preserving Proximity Tracing). Devised by scientists from eight European universities, DP-3T changes the anonymous codes regularly, which makes it impossible to associate one code with one phone, or person. It also keeps all the codes, sent and received, on users’ phones, unless an infectious person’s ‘sent’ codes need to be uploaded for cross-checking, via encrypted channels. The cross-checking takes place on users’ phones, not in the central database. This means that nobody has the whole picture or can identify the people who received your codes.

CLOSE CALLS

The NHSX app currently being tested uses a ‘centralised’ model, where all the codes from the phones would be uploaded to one central database, and the cross-checking would be done there. At the time of writing, NHSX still hopes to make this app work, because it wants to be able to use the aggregated data to improve its models and predict the course of the disease. The effectiveness of the app relies on having over half the population running it, which means 80 per cent of smartphone users. Between the inconvenience of an app that keeps going to sleep, and the trust issues of having a database track who you are meeting even if you’re not infectious, it could be more attractive for NHSX to switch direction.

Though it would clearly be inconvenient to change at this late stage, it wouldn’t prevent NHSX from asking for other information, such as location data. Given that 3.5 million people are already using the ZOE COVID symptom-tracking app, many of us are willing to donate our personal health data for research. But a recent Opinium survey found only 52 per cent of Britons were currently likely to download a contact-tracing app, which would make it very ineffective. Perhaps the way forward is to separate the two functions, and have one NHSX app for data collection and a privacy-protecting version to trace contacts. That way, those who want to donate data can do so, and those who want to safeguard their privacy can still help with contact-tracing and slow the spread of COVID-19. SF

by **TIMANDRA HARKNESS** *(@TimandraHarknes)*
Timandra presents the BBC Radio 4 series, FutureProofing *and* How To Disagree. *Her latest book is* Big Data: Does Size Matter? *(£16.99, Bloomsbury Sigma).*

NHS

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More investment is needed to drive practical action committed to restoration within woods

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61%

ancient semi-natural woodland

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3,770 hectares of PAWS is being restored by the Woodland Trust on its own estate

1,064

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↗ Fitbit could help diagnose sleep apnoea p43

INNOVATIONS

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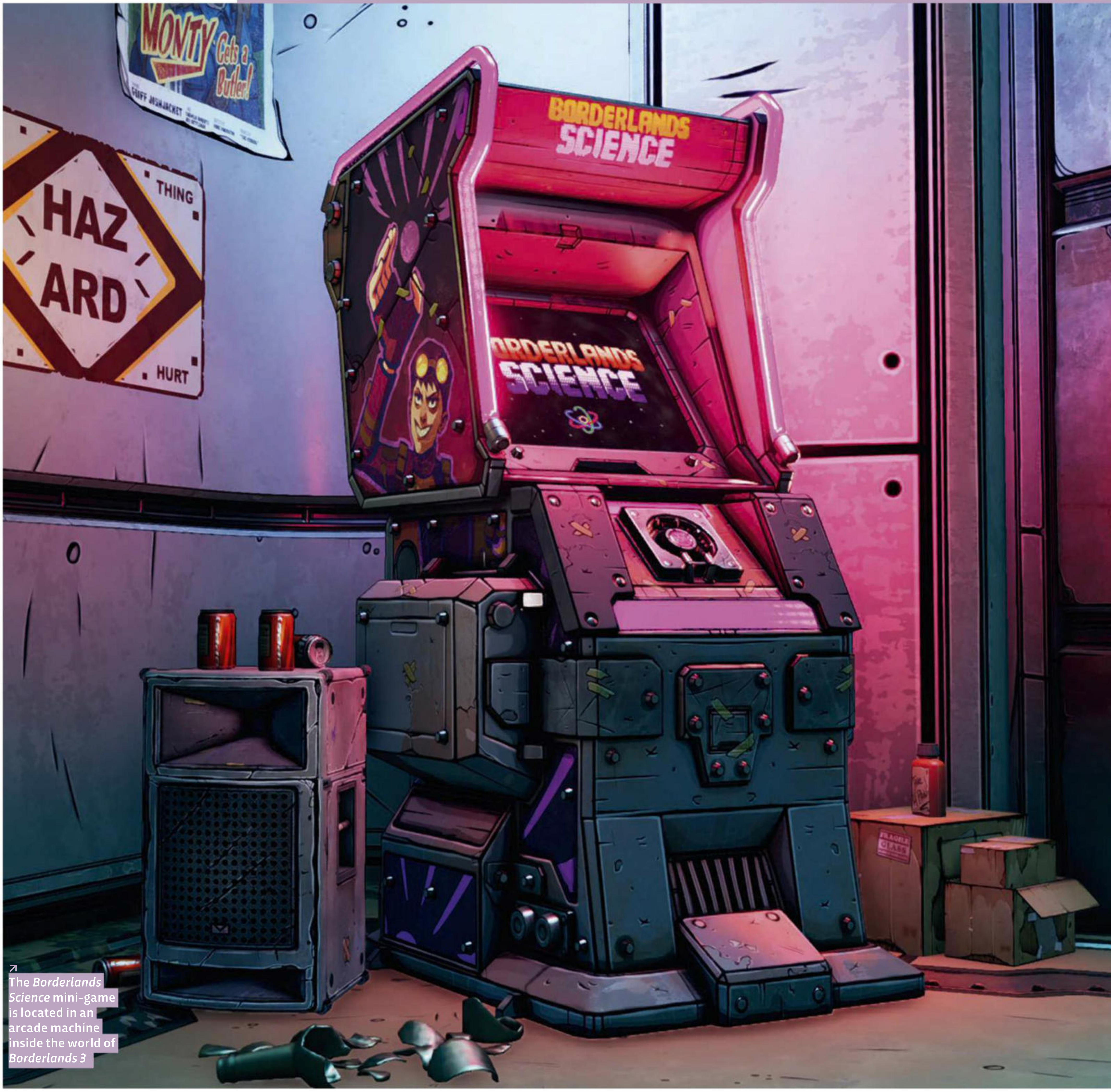
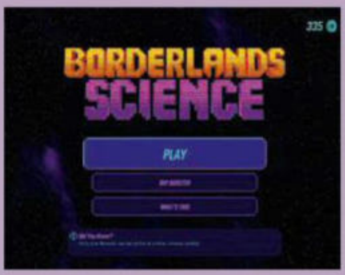

MONTY Gets a Butler!
HAZ ARD
THING
HURT
BORDERLANDS SCIENCE
BORDERLANDS SCIENCE
FRAGILE GLASS

↗ The *Borderlands Science* mini-game is located in an arcade machine inside the world of *Borderlands 3*

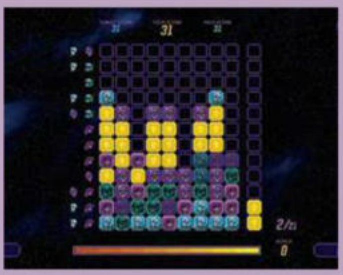
STEP BY STEP

Start playing



Borderlands Science is housed in an arcade cabinet on *Sanctuary*, the ship players use to move from world to world. Jump in and be greeted with a tutorial.

Match blocks



Line up rows of similar colours by shifting columns of blocks. Each block symbolises a nucleotide of bacterial DNA. More matches = bigger score.

Get rewards

Hit the target score in the arcade game and you will be rewarded with random loot, like guns and shields, that you can use in the game world.

GAME ON

Gamers solve 36 million puzzles... for science! (and loot)

***Borderlands* players crunch through data to help scientists map the human microbiome**

Back at the start of April, a team of scientists and coders set up a mini-game inside the world of *Borderlands 3* in the hope that the game's huge playerbase would lend their brainpower to identifying the DNA of microbes in the human microbiome – the collection of tiny organisms that live in the body and influence our health. In the space of one month, the game developers Gearbox have seen some 700,000 players take part in the mini-game that analyses snippets of DNA harvested from the gut via poo samples.

The players didn't need any medical knowledge (or rubber gloves) to get involved. Different building blocks of DNA, called nucleotides, from pairs of bacteria were converted into different coloured squares and arranged into columns. The goal for players was to align the coloured squares of each column with the ones next to it, by moving them up and down, while introducing as few gaps (empty squares) as possible. In effect, this matching game tells scientists how similar the DNA sequence of bacteria A might be to bacteria B – if lots of blocks line up neatly in rows, then A and B share a similar ancestry and function. And if bacteria B is unidentified, but is a close relative of A, then we now understand a lot more about B.

> "SOME 700,000 PLAYERS HAVE TAKEN PART IN THE GAME THAT ANALYSES DNA FROM GUT BACTERIA"

In the game, the target score was the score achieved by an algorithm trying to carry out the same task, so the gamers were challenged with toppling it to earn in-game rewards.

It's the kind of task that an AI typically struggles with, because there are goals at odds with one another (maximise alignments and minimise gaps) so the gamers would typically beat the score and some would go on to set their own high score. Each outcome will help scientists, who are working on the project at McGill University and the Microsetta Initiative, to develop different ways to solve the problem and ultimately train an AI to do the job as well as humans can.

It's early days, but the results are already promising. It seems that on average 60 per cent of the solutions were where the computer put them, and 40 per cent were positioned better, thus improving the accuracy of their identification process. *Borderlands 3* players have now completed 36 million puzzles and when they hit 40 million the team will move on to bigger more complicated sequences in Phase 2.

The ultimate goal of all this puzzle-solving is to identify the bacteria living inside us, and their functions. The make-up of our microbiome has been linked to many diseases and conditions, including obesity, depression, cancer and more. If we can understand this microbial ecosystem, then we can come up with better treatments and interventions. The data is all open source so that future teams can benefit from the findings.

TAKE-TWO INTERACTIVE SOFTWARE

ON TEST

LEXILIGHT

A reading lamp designed for dyslexia

Can a smart light help people to read more easily?

The Lexilight uses pulsed light to help dyslexics to read

In the UK, around 10 per cent of people have dyslexia. Dyslexia is entirely subjective to the person who suffers from it. However, for some context, I am pretty much in the middle of the spectrum. When reading, I get rivers of light running through text, along with jumping letters and frequent skipping across words or lines. I have used coloured overlays in the past, and have glasses with coloured lenses that improve my reading experience.

A small study published in 2017 in the journal *Proceedings Of The Royal Society B* found evidence that one cause of dyslexia could be down to a patch of light-sensitive cells in the eye. It said that in non-dyslexics, the cells are differently arranged between the two eyes, with information from one eye overriding the other. In dyslexics, both eyes have the same pattern. There is therefore no dominant eye, meaning that two pieces of information are sent to the brain at the same time, which can cause mirror images.

Lexilife has launched an LED reading lamp, the Lexilight, that claims to reduce the mirroring effect by using pulsed light to allow one eye to take dominance. Several parameters of the lamp can be adjusted, so it can be personalised to suit the user.

The Lexilight is a well-made and pleasing design. It is lightweight and comes with a protective carry case to keep it safe when you're on the move. On the desk, it's extremely sturdy, and you can arrange it to face the screen when you're working on a computer. Its stability is reassuring, because the adjustments needed to get the best result are precise, and much fiddling is required on the initial setup. However, once you've sorted your personal settings, you shouldn't need to do anything more than switch the light on and off as needed.

Using the light for the first time is a slightly strange experience. The instructions weren't very in-depth, so I had no idea quite what to expect or what I should be aiming for with the settings.

Regardless of which settings I went for, I was still seeing the rivers of light between words and, in some cases, felt the pulsing of the Lexilight was making things worse. It was only when I switched off the Lexilight function, and then looked at the page with the normal lamp mode, that I recognised the benefits of having the function switched on. For me, when I'd adjusted the Lexilight to suit me, each word appeared clearer and more distinct from any words around it. It was a lot easier to focus on the exact word I was reading and that helped me stay on the correct line too. My rivers of light remained though, and I feel that my assumption that I would suddenly be 'cured' clouded my initial response to the light.

I would add, though, that some clearer idea of the proposed benefits should be mentioned within the manual. For me, this wasn't a miracle dyslexia cure, but it was a useful addition to aid my reading. I am sure that there will be some dyslexics out there who receive even more of a benefit, particularly if they experience the mirroring effect. Plus, you can try the light for 30 days, and can get a refund if you're not satisfied.

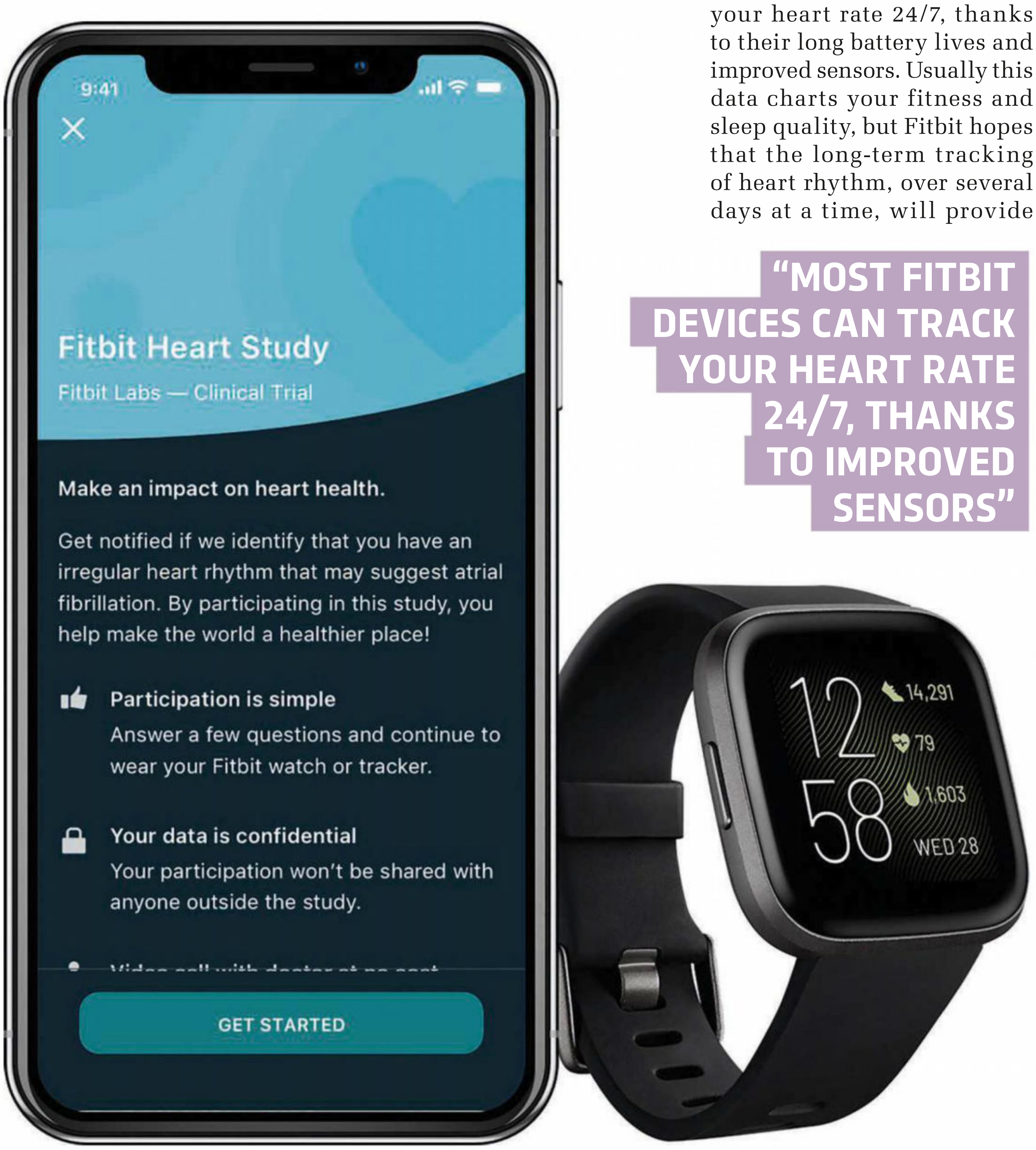
£499, lexilife.com

—

by **TOM HIRD** (@TheBlowfish)

Tom is a broadcaster and author.

Fitbit investigates whether wearables can diagnose heart conditions



Make an impact on heart health.

Get notified if we identify that you have an irregular heart rhythm that may suggest atrial fibrillation. By participating in this study, you help make the world a healthier place!

Participation is simple
Answer a few questions and continue to wear your Fitbit watch or tracker.

Your data is confidential
Your participation won't be shared with anyone outside the study.

Fitbit has kick-started a piece of research, involving hundreds of thousands of users, to find out if its heart-rate tracking tech could spot undiagnosed health conditions. In particular, the Fitbit team want to test if they can identify Atrial Fibrillation (AFib), an irregularity in the heart's rhythm that can be a precursor to stroke.

Most Fitbit devices can track your heart rate 24/7, thanks to their long battery lives and improved sensors. Usually this data charts your fitness and sleep quality, but Fitbit hopes that the long-term tracking of heart rhythm, over several days at a time, will provide a window into the wearer's heart health.

> "MOST FITBIT DEVICES CAN TRACK YOUR HEART RATE 24/7, THANKS TO IMPROVED SENSORS"

To track heart rate, certain Fitbit models use technology called photoplethysmography – a technique that detects changes in blood volume in the tissue just beneath the skin. It works by shining a light into your skin and monitoring the light that bounces back to identify changes in blood flow, volume and oxygenation. This technology is commonly found in accident and emergency departments around the world in the shape of small clips that nurses clamp to your finger to check your oxygen levels.

Participants in the experiment who receive a notification about an irregular heart rhythm will be given a virtual appointment with a doctor in the US free of charge – and could potentially receive an electrocardiogram (ECG) patch in the mail to check the diagnosis more thoroughly.

Fitbit isn't the only one testing whether wearable tech can be of use in a medical setting. Apple has looked into whether it could detect AFib too, with moderate success. The tech giant has also been investigating whether its smartwatches could provide insight into other conditions, like seizures and binge-eating.

Indeed, this study by Fitbit is just one piece in a broader initiative by the company to use its tech and huge customer base to develop early diagnosis tools. Earlier this year, Fitbit partnered with Scripps Research and Stanford Medicine to study the role that wearables could have in detecting, tracking and containing infectious diseases like COVID-19.

Ideas we like...

Eco-conscious trainers

Get your kicks, without costing the planet. That's the idea behind these new trainers from Allbirds.

The design follows the trends in running shoes over the last few years: a mesh upper provides lightness, the flared heel adds stability and a mixed density sole adds springiness. Where it differs is in its materials and manufacturing. The shoe is constructed out of materials made from wool, eucalyptus tree fibre and sugarcane rather than the usual plastics and rubbers derived from fossil fuels. And the manufacturing process minimises carbon footprint and water use. These Dashers have a footprint of 8kg of CO_2 – 30 per cent less than an average trainer.

Allbirds Dasher
£120, allbirds.com

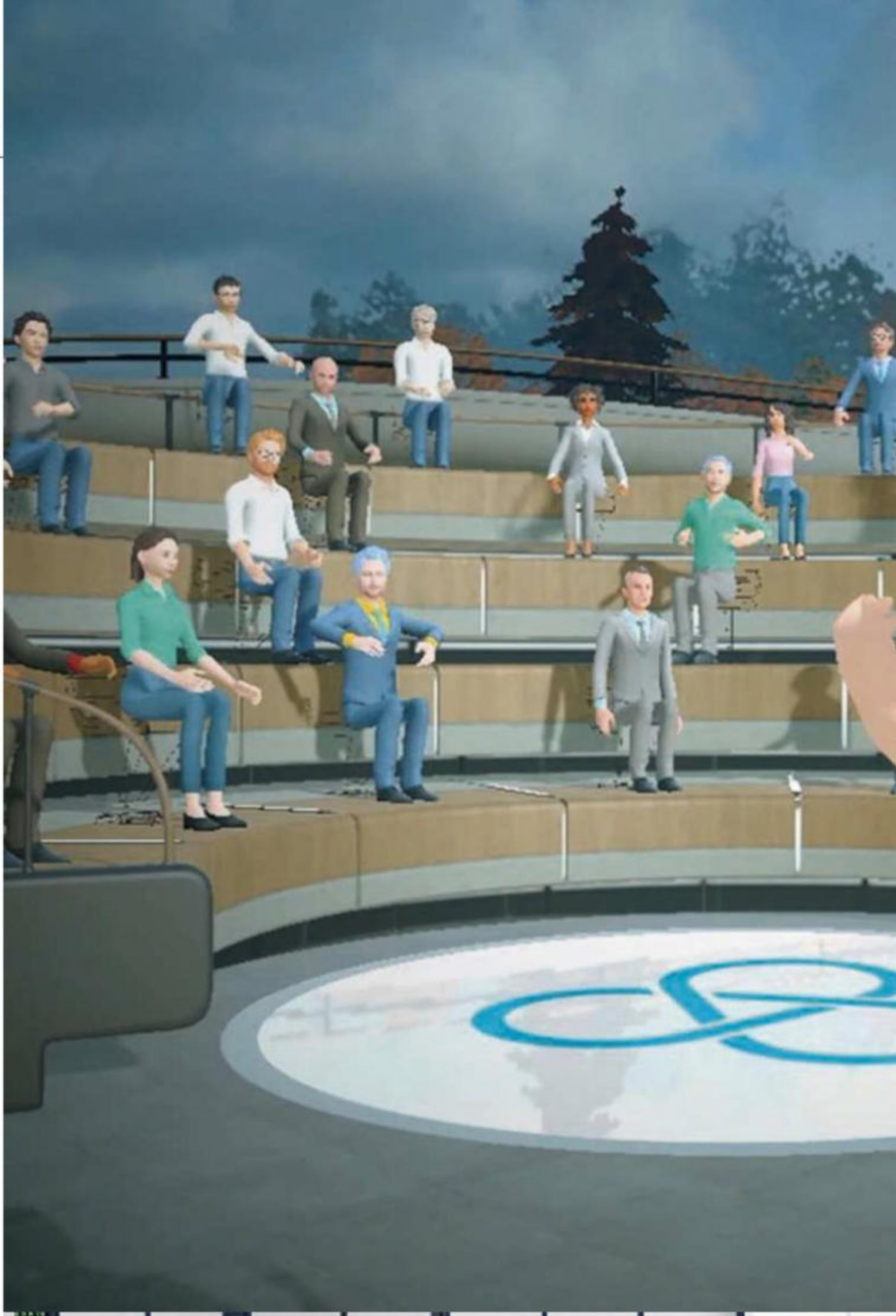
A smart-looking smartwatch

18°C
HEART 60
3.824 STEPS

Many companies follow the Apple design book when it comes to smartwatches, so it's nice to see something different. The Tag Heuer Connected is completely circular, free of protrusions or odd-shaped displays, and is fronted by a scratch-resistant sapphire crystal that protects a high-resolution OLED touchscreen. You can choose how the display looks with just a few clicks.

Despite the boardroom appearance, the Tag Heuer Connected is still built with fitness tracking in mind, with GPS onboard to follow your fitness activities, including running, cycling and golf.

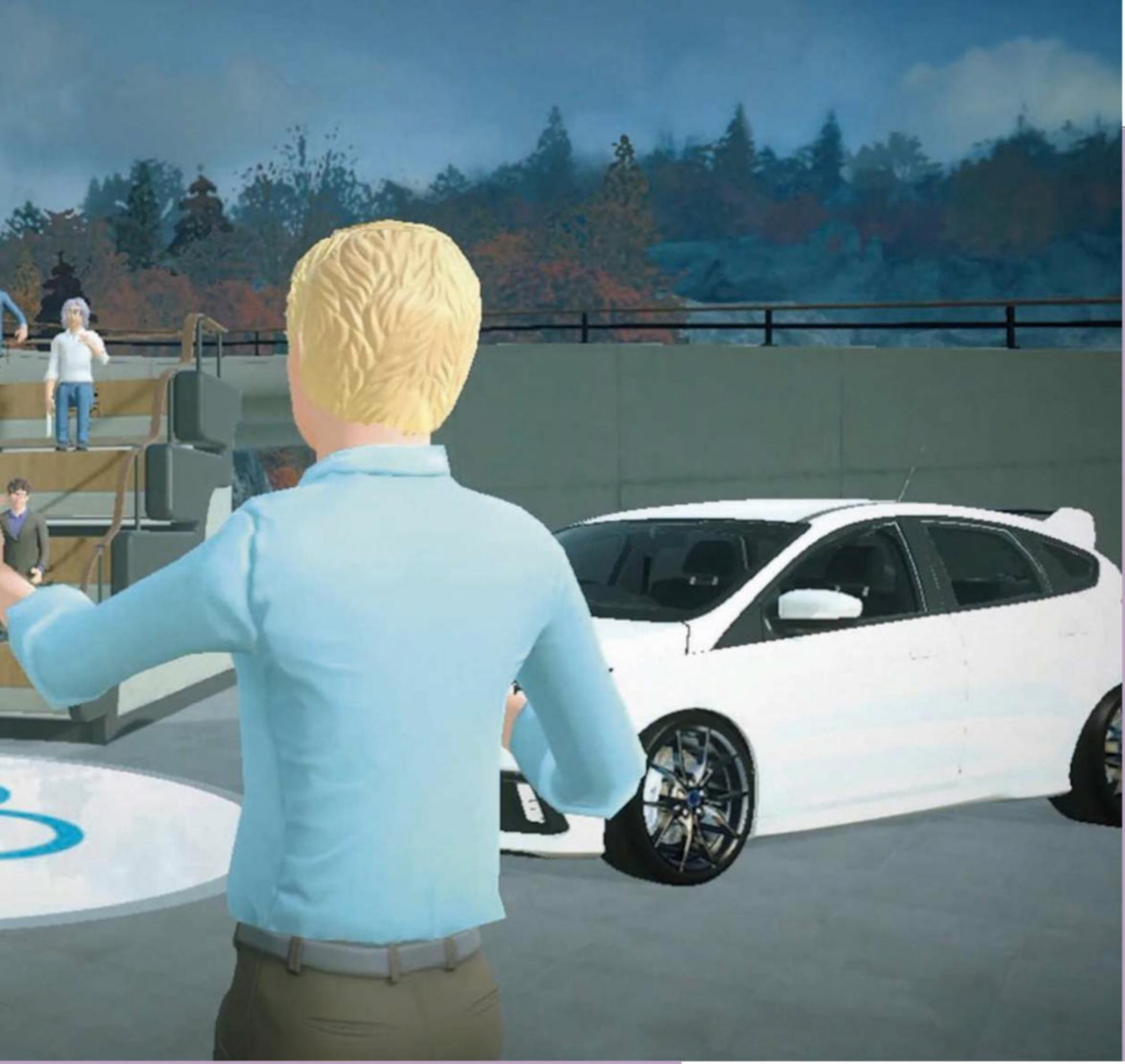
Tag Heuer Connected
From £1,495, tagheuer.com



A bouncy foam mattress

Memory foam mattresses killed the bedspring, or did they? This new innovation from Simba has put springs back into its mattress (2,500 of them to be precise). These small, individually wrapped miQro® springs are cone-shaped to support your weight better, and allow air to move between you and the foam beneath. Simba claims that this combo of foam and springs offers the best of both worlds, making for a comfier, supple mattress that's cooler than memory foam alone.

Simba Hybrid Pro
From £549.30 for a single, simbasleep.com



←

VR meetings

While many of us were hopeful that working from home might spell the end of frivolous office meetings, it seems they've been replaced by Zoom calls, Team Meetings and Google Hangouts. Even friends and family are getting in on the action now. So why not throw some VR into the mix? If you've got two Vive VR headsets, Vive Sync lets you take your next meeting in virtual reality. It sounds cheesy, but it's useful when it comes to professions like engineering and design. You can load 3D models into the virtual space, move the object and inspect it. We attended a virtual press conference in this way last year and were pleasantly surprised at how much more immersive it was than a video conference.

HTC Vive Sync
sync.vive.com

↓

Phones working the night shift

Most modern smartphones have more processing power than my last laptop. The *DreamLab* app uses that computing resource at night, when you're presumably asleep, and harnesses it to help scientists run simulations and computational models, just like a networked supercomputer. It's currently offering this resource to researchers looking to create vaccines and treatments for COVID-19.

Vodafone DreamLab
Free, vodafone.co.uk/mobile/dreamlab

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Apnoea-diagnosing smartwatches

Fitbit has unlocked a new piece of tech in its fitness trackers. Many of its devices already take your pulse by shining a light into your blood vessels and monitoring changes in the light that bounces back. Now, with some tweaking to its software, Fitbit can use the same hardware to keep an eye on the volume of oxygen in your blood. There's not a lot of use in this in the gym – unless you train at the top of a mountain where the air's a bit thinner – but the reading can be useful in diagnosing sleep apnoea, a condition where people stop breathing in the middle of the night. It is estimated to affect some 1.5 million people in the UK, many of those undiagnosed.

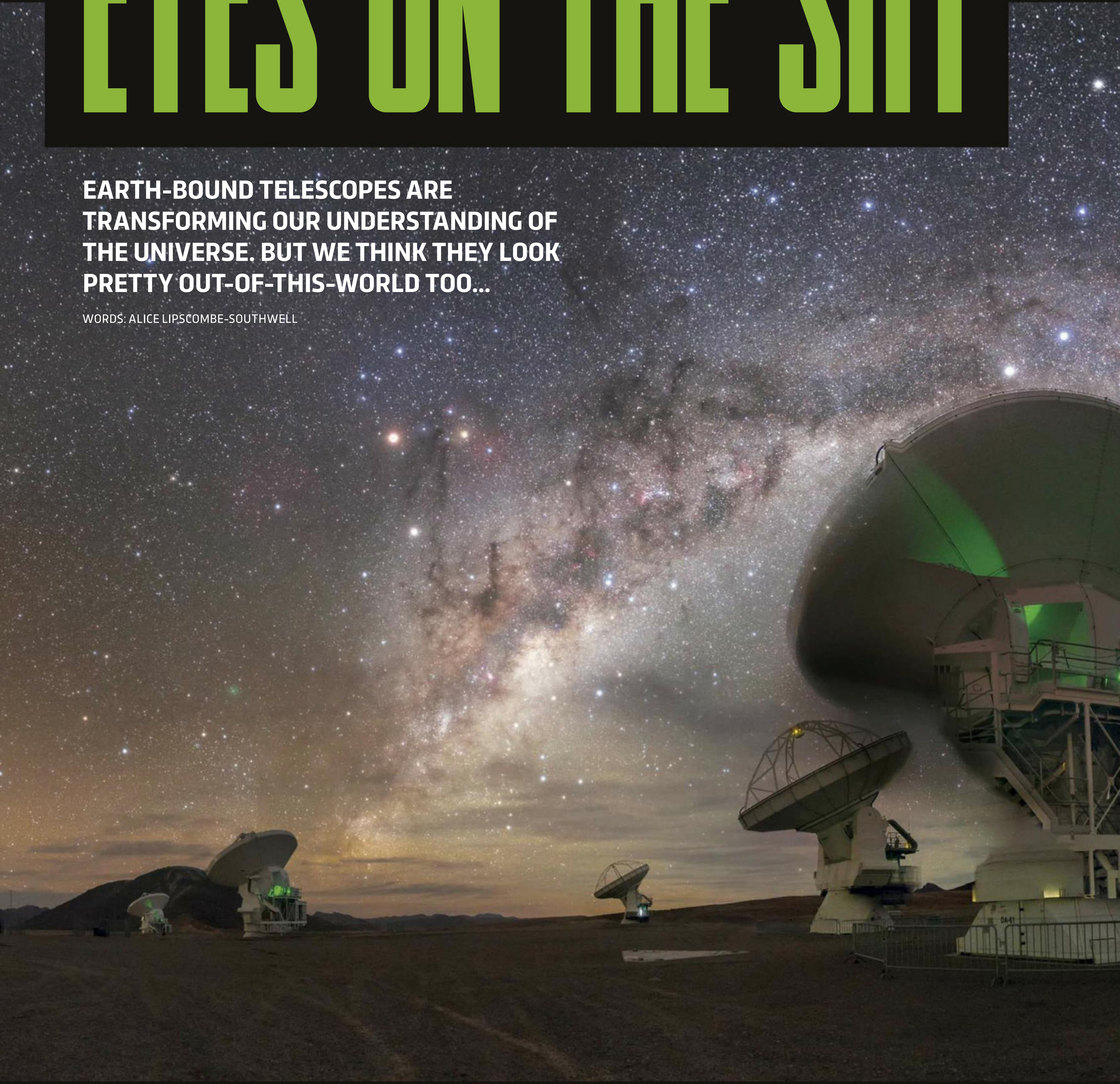
Some Fitbit models, including the Charge 4 pictured here, will now track your oxygen variability (what's called 'pulse oximetry') during the night. If you find you have a high number of episodes where your oxygen is low, it might be worth talking to your doctor.

Fitbit Sp02 Monitor
fitbit.com

EYES ON THE SKY

EARTH-BOUND TELESCOPES ARE TRANSFORMING OUR UNDERSTANDING OF THE UNIVERSE. BUT WE THINK THEY LOOK PRETTY OUT-OF-THIS-WORLD TOO...

WORDS: ALICE LIPSCOMBE-SOUTHWELL



PEEK INTO THE PAST

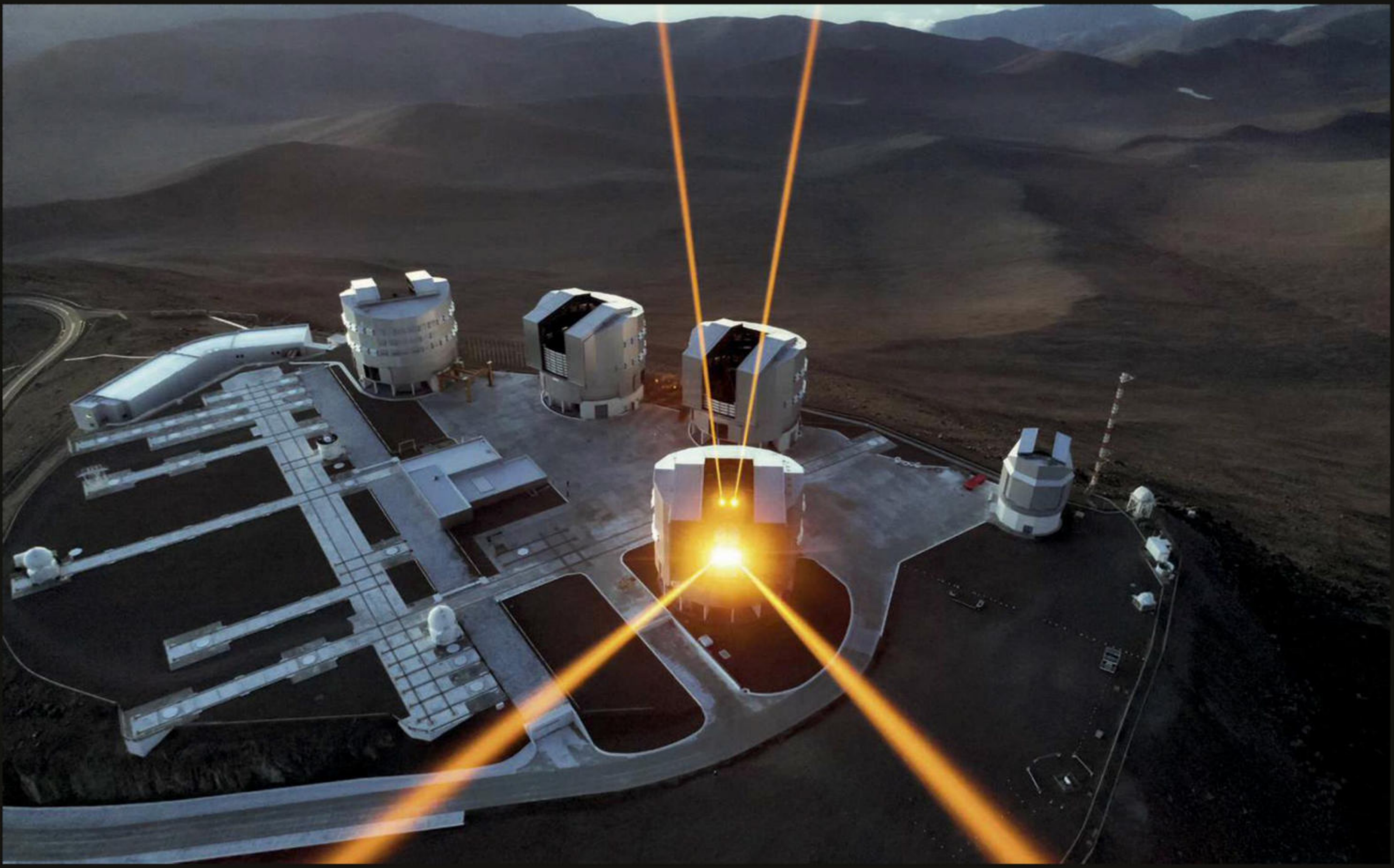
ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY (ALMA)

Chajnantor plateau, Atacama Desert, ***Chile***

The Atacama Desert in Chile is an astronomer's paradise. Thanks to its high altitude, cold nights, scant precipitation and lack of pollution, it boasts some of the clearest night skies on the planet. That's why the European Southern Observatory (ESO) – an astronomical research organisation of 16 countries – worked with Chile to set up powerful ground-based telescopes in the desert, including the Atacama Large Millimeter/submillimeter Array (ALMA). Beginning observations in 2011, the high-tech telescope consists of 66 precise antennas that can be arranged in different ways to give a variable zoom, capturing sharper detail than the Hubble Space Telescope. ALMA studies light with wavelengths of around a millimetre, originating from the Universe's coldest objects that exist at temperatures at just above absolute zero. These objects include the molecular gas and dust clouds that are the building blocks of galaxies, stars and planets. By studying these regions of the Universe, scientists will be able to decipher the mysteries of planetary formations as well as our cosmic origins. ▶

P HORÁLEK/ESO

The lasers seen here act as an artificial 'guide star', which allows the telescope to compensate for turbulence in the Earth's atmosphere to obtain clearer images



DECIPHER THE UNIVERSE

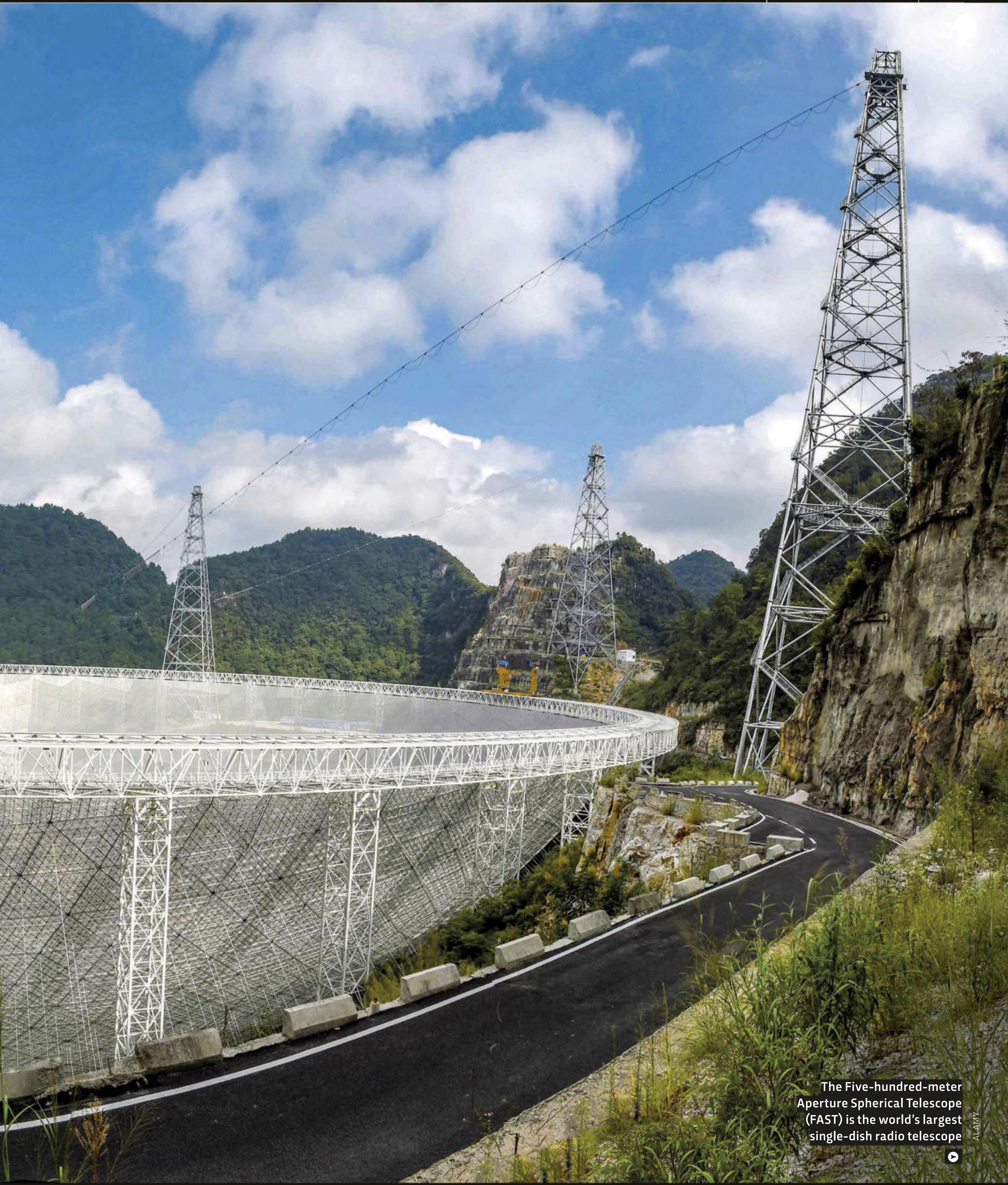
VERY LARGE TELESCOPE (VLT)

Cerro Paranal, Atacama Desert, ***Chile***

Around 500 kilometres away from ALMA, on the other side of the desert, is the Very Large Telescope (VLT). It consists of four 'unit telescopes', each named after a celestial object in the Mapuche language – spoken by the indigenous population of Chile – and complemented by four moveable 'auxiliary telescopes'. Just one of the unit telescopes can see objects four billion times fainter than is visible with the human eye. Alternatively, the telescopes can work together to form a huge 'interferometer', allowing astronomers to view much finer detail than is possible by using each telescope individually.

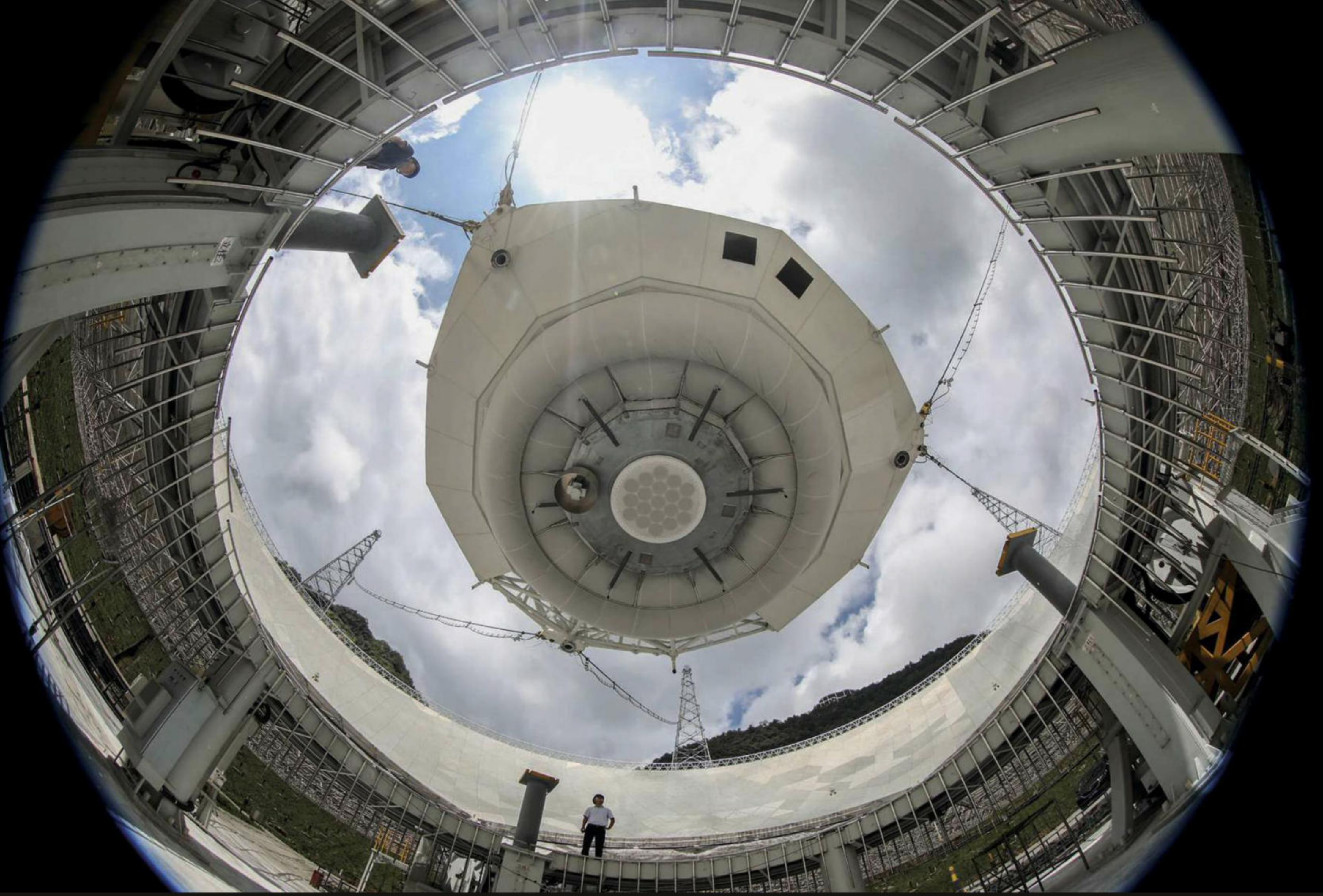
The VLT first started operations in 1998 and has transformed our understanding of the Universe, with its results leading to an average of more than one peer-reviewed paper every day. Some of its most iconic work includes testing Einstein's General Relativity by tracking the movement of a star passing through the gravitational field around the Milky Way's supermassive black hole. However, it has also calculated the age of ancient stars in the NGC 6397 cluster, and has analysed the atmosphere of a super-Earth exoplanet, helping scientists to learn more about worlds beyond our Solar System. The VLT was even able to detect carbon monoxide molecules in a galaxy almost 11 billion light-years away.

G HUDEPOHL/ESO, V FORCHI/ESO X2



The Five-hundred-meter Aperture Spherical Telescope (FAST) is the world's largest single-dish radio telescope

ALAMY



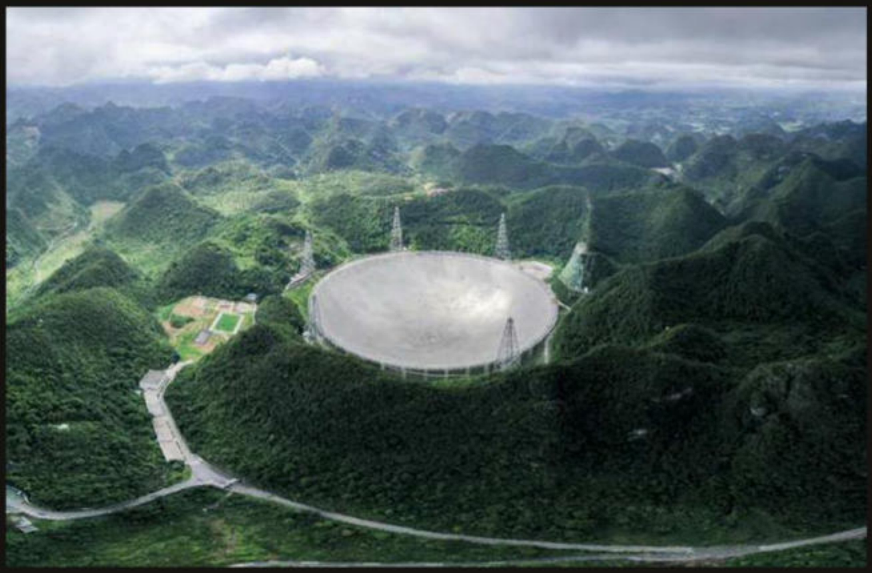
WHAT A DISH!

FIVE-HUNDRED-METER APERTURE SPHERICAL TELESCOPE (FAST)

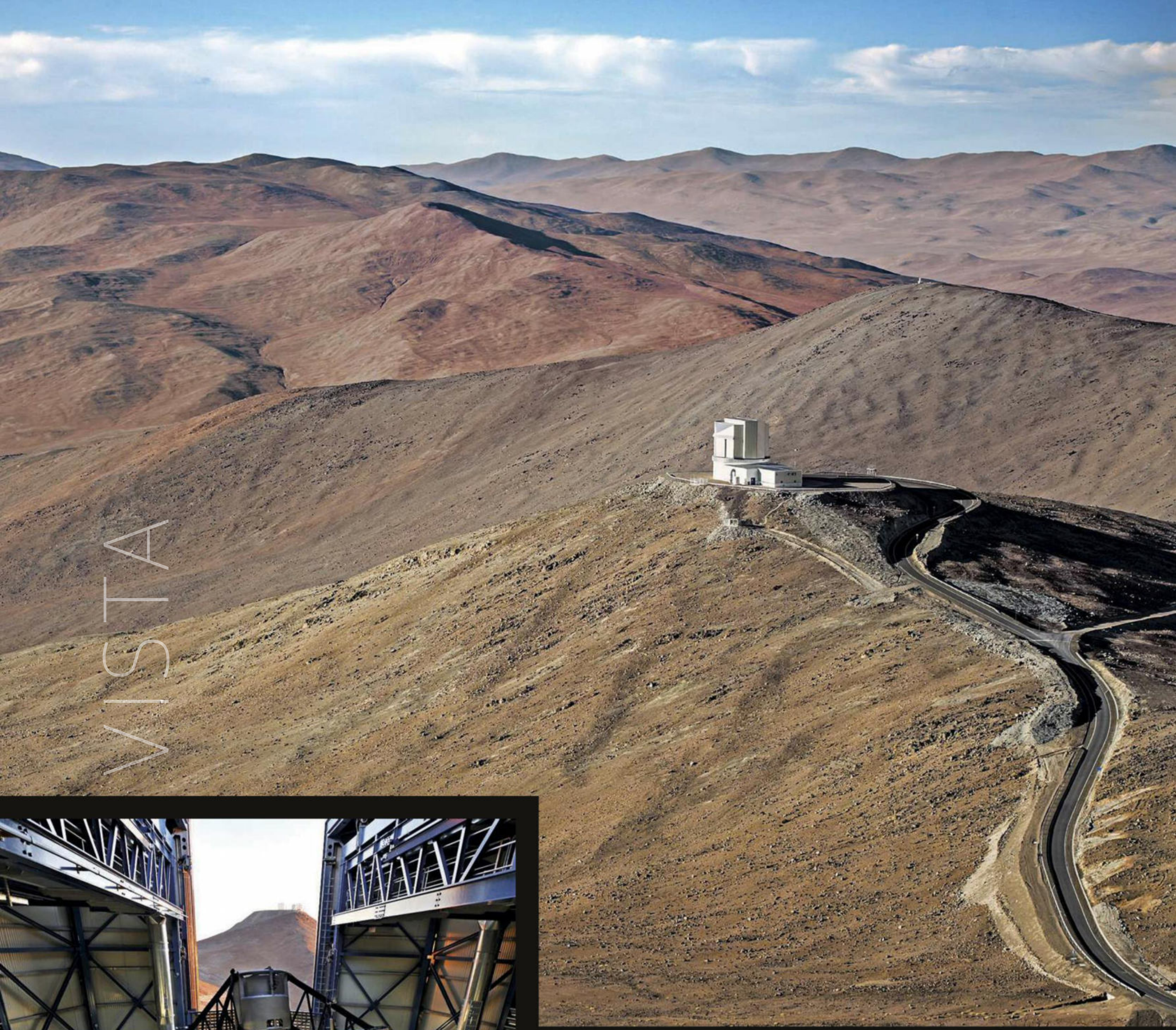
Pingtang County, Guizhou, ***China***

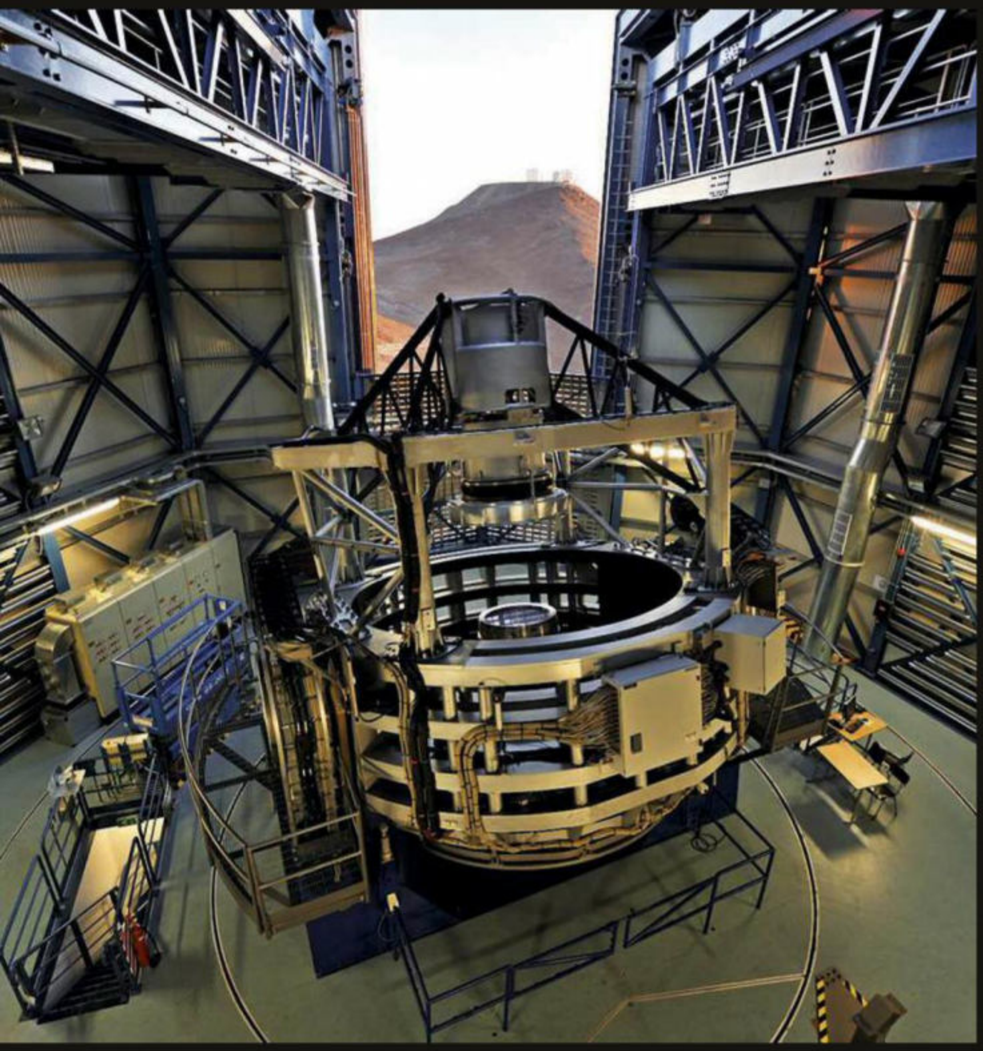
On the other side of the world in China's remote and mountainous Pingtang County lies the newest telescope in our roundup, the Five-hundred-meter Aperture Spherical Telescope (FAST). This radio telescope started formal operations in January 2020, and consists of an enormous 500m-diameter dish composed of 4,450 triangular metal panels that can be adjusted to target different areas of the sky. The dish focuses incoming radio waves onto a receiving antenna. It first opened to astronomers in autumn 2019 and is designed to search the skies for pulsars, fast radio bursts (FRBs), and potentially alien life. Pulsars were first spotted by Jocelyn Bell Burnell and Antony Hewish back in the 1960s and were initially dubbed LGMs for 'Little Green Men', until they were identified as highly magnetised, rapidly rotating neutron stars that can only be detected by radio telescopes. FRBs were discovered back in 2007, and are brief, energetic bursts of radio emissions that take place all over the cosmos. Their precise cause has not yet been identified.

FAST



ALAMY X3, G HUDEPOHL/ESO, A TUDORICA/ESO





MAKE THE INVISIBLE VISIBLE

VISIBLE AND INFRARED SURVEY TELESCOPE FOR ASTRONOMY (VISTA)

Cerro Paranal, Atacama Desert, ***Chile***

At the same site as the VLT is the Visible and Infrared Survey Telescope for Astronomy (VISTA), operating since 2009. Also owned by ESO, VISTA is equipped with a sensitive near-infrared camera that can see things that are invisible to the human eye. This means that it can look for bodies such as brown dwarfs, which are incredibly faint in terms of visible wavelengths, as well as distant objects like quasars and other galaxies. But it can also peer through the clouds of dust that obscure swathes of the cosmos, allowing it to glimpse the individual stars at the centre of the Milky Way, enabling scientists to map our Galaxy in much greater detail. Some of the most stunning images taken by VISTA so far include the Flame Nebula, the Orion Nebula and the Lagoon Nebula, all located thousands of light-years away. SF

by ALICE LIPSCOMBE-SOUTHWELL
Alice is the managing editor for BBC Science Focus *and* BBC Science Focus Collection.

A NEW WAVE OF BACTERIA IS COMING SOON...

by **COLIN BARRAS**

We get inside the labs that are growing beneficial bacteria to gobble up pollution, harvest waste, generate energy and help keep us healthy

We're in trouble. Our over-reliance on fossil fuels and our taste for foods with a high carbon footprint is causing disruptive climate change. Our throwaway society has flooded the land and seas with plastic pollution. And we face a growing public health crisis triggered by the rise of disease-causing microbes that we cannot kill with antibiotics.

Now for the good news. The last few years have brought promising evidence that we might be able to pull carbon dioxide (CO_2) out of the atmosphere and slow the pace of climate change, that we have the potential to grow high-quality protein without the large carbon footprint, and that we can clean up our pollution and blunt the impact of antibiotic resistance. The common element in all these potential breakthroughs? Bacteria. As unlikely as it might sound, our future health and happiness might be secured by these humble microbes. ▶

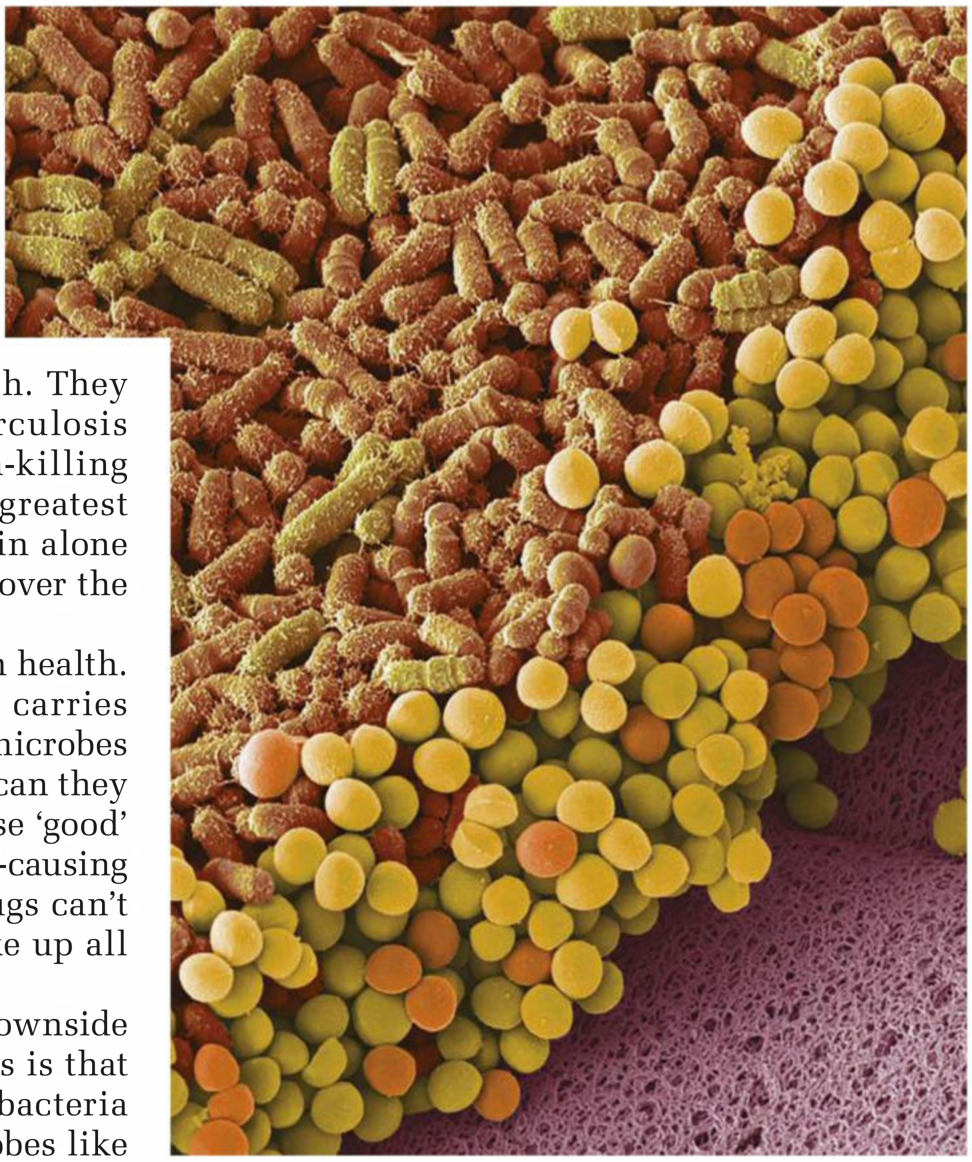
WHAT ARE BACTERIA?

BACTERIA ARE MICROSCOPIC, SINGLE-CELLED LIFE FORMS. BACTERIAL CELLS TEND TO BE SMALLER THAN HUMAN CELLS, AND THEY HAVE A SIMPLER INTERNAL STRUCTURE. BUT DESPITE THIS SIMPLICITY, BACTERIA ARE ASTONISHINGLY SUCCESSFUL. THEY CAN LIVE ALL OVER THE PLANET IN MANY DIFFERENT ENVIRONMENTS, INCLUDING HOT SPRINGS, HYPER-SALTY LAKES, THE HIGHEST MOUNTAINS AND THE DEEPEST OCEANS.

ILLUSTRATION: MAGIC TORCH

HUMAN HEALTH

Beneficial bugs that heal the body



Scanning electron microscope image of bacteria cultured from human faeces

Bacteria can be terrible for human health. They trigger deadly diseases including tuberculosis and cholera. As a consequence, bacteria-killing antibiotics have been called one of the greatest discoveries of the 20th Century: penicillin alone has saved an estimated 200 million lives over the last 80 years.

But bacteria can also be great for human health. Recently, we've learned that each of us carries trillions of beneficial bacteria and other microbes on our skin and inside our guts. Not only can they help us extract energy from our food, these 'good' bacteria sometimes protect us from disease-causing 'bad' bacteria. This is because the bad bugs can't colonise our guts if the good bacteria take up all of the available space.

Or they do unless we disturb them. A downside of taking a prolonged course of antibiotics is that the drugs can kill off some of the good bacteria in our gut, offering disease-causing microbes like *Clostridioides difficile* an opportunity to take up residence there. *C. difficile* infections can cause diarrhoea, nausea and fever.

However, studies over the past couple of decades have highlighted a surprising way to treat *C. difficile* infections. If a sample of poo from a healthy volunteer is transferred into the diseased gut, the good bacteria it contains can outcompete the *C. difficile* growing there.

These 'faecal transplants' can help treat other diseases, too. But for the moment it isn't clear exactly how. Prof Seth Bordenstein, from Vanderbilt University in Tennessee, studies the interactions between animals, microbes and viruses, and points out that we don't know exactly which bacteria in the poo samples are responsible for the health benefits.

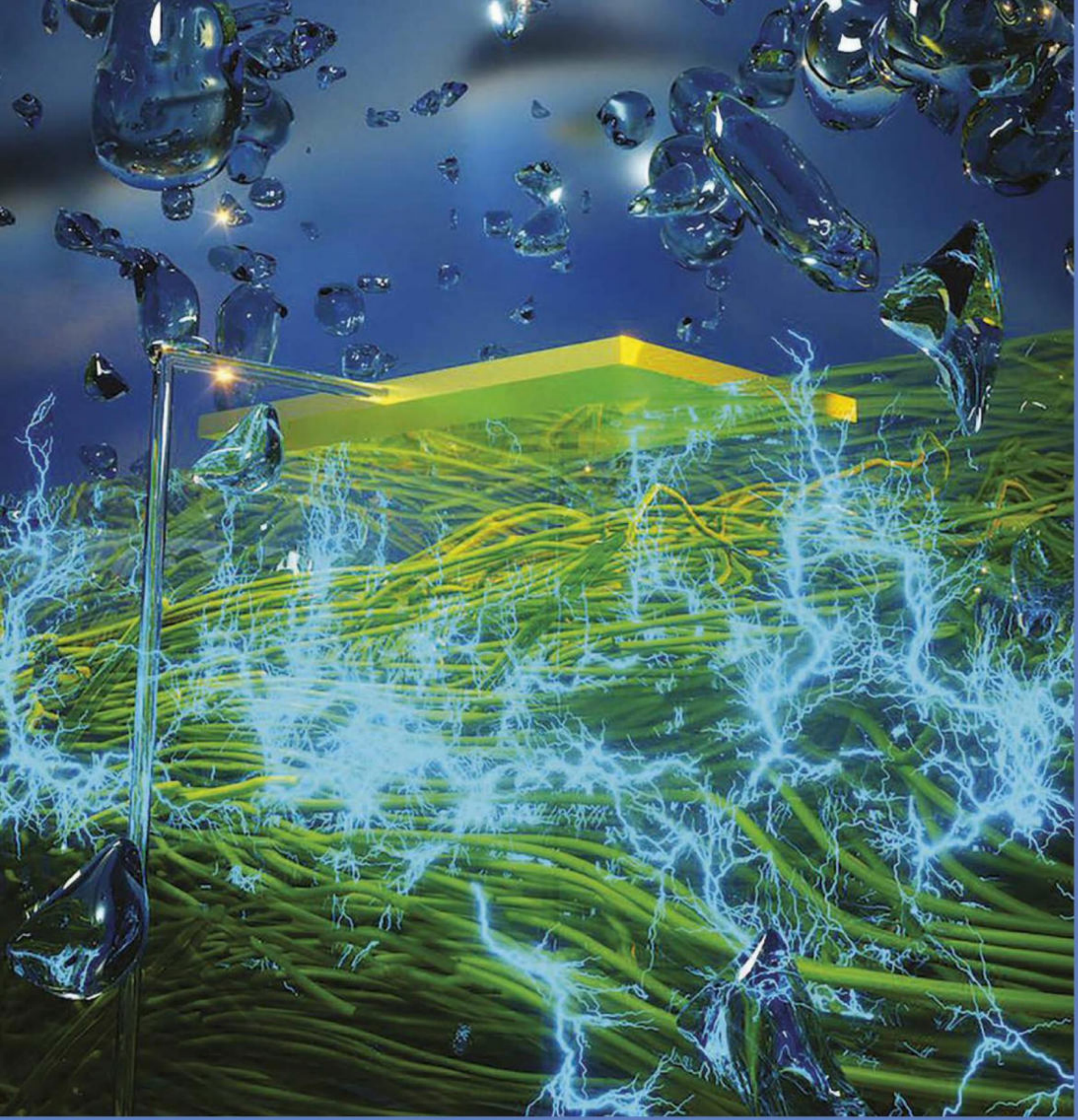
At the opposite end of the spectrum, there are bacteria we could use in medicine precisely *because* we know how they work. This is particularly true of *Escherichia coli*, a mostly harmless species that is at home in the human body. Researchers have learned so much about *E. coli* through the decades that it is now essentially a tiny, programmable biocomputer that could be used to treat disease.

> "Some strains of *E. coli* can seek out and grow inside tumours, making them a suitable vehicle to deliver cancer therapeutics"

"Some probiotic [health-benefitting] strains of *E. coli* can seek out and grow [inside cancer tumours], making them a suitable vehicle to deliver cancer therapeutics," says PhD student Candice Gurbatri at Columbia University in New York.

Gurbatri is working with Prof Tal Danino, also at Columbia, to harness this tumour-seeking behaviour. They have inserted extra DNA into *E. coli* that allows the bacteria to manufacture potent cancer-fighting molecules called 'nanobodies'. Another snippet of extra DNA encourages *E. coli* cells to self-destruct once they have multiplied within the tumour, showering the cancerous tissue with the nanobodies. The end result is a form of *E. coli* that, when swallowed, will target and help destroy tumours.

Earlier this year, Gurbatri, Danino and their colleagues tested the approach in mice with promising results. But there will be regulatory hurdles to clear before human trials can begin. There are, understandably, ethical and safety concerns around the idea of treating people with genetically engineered microbes.



Artist's impression of the 'Air-gen' device that generates electricity from thin air

RENEWABLE ENERGY

The promise of bacterial biofuels

GETTY IMAGES, YAO/LOVLEY LABS/UNIVERSITY OF MASSACHUSETTS AMHERST

Bacteria are extraordinary chemists. Not only can they manufacture powerful anti-cancer drugs, they can also churn out renewable biofuels.

Earlier this year, Prof Nigel Scrutton at the University of Manchester and his colleagues published a study showcasing this potential. They modified an enzyme called 'fibroblast activation protein' (FAP) that's found in many bacteria, so that it breaks down human food waste through fermentation and generates propane gas. Propane is used in transportation fuel and in domestic heating and cooking.

This on its own is a promising starting point for a commercially viable system. But Scrutton and his colleagues have boosted their chances of industrial success by inserting their enzyme into *Halomonas* bacteria, one of the few microbes able to survive in unusually salty water. Most industrial fermentation systems are built from steel that must be carefully sterilised to make sure no rogue microbes enter the fermenter and reduce its efficiency. But as a *Halomonas* fermentation system uses salty water to operate, it saves on the need for this costly sterilisation because essentially nothing but *Halomonas* can survive.

"You could perform this fermentation even in a cheap reactor made out of a material like plastic," says Scrutton. "It keeps the capital investment down."

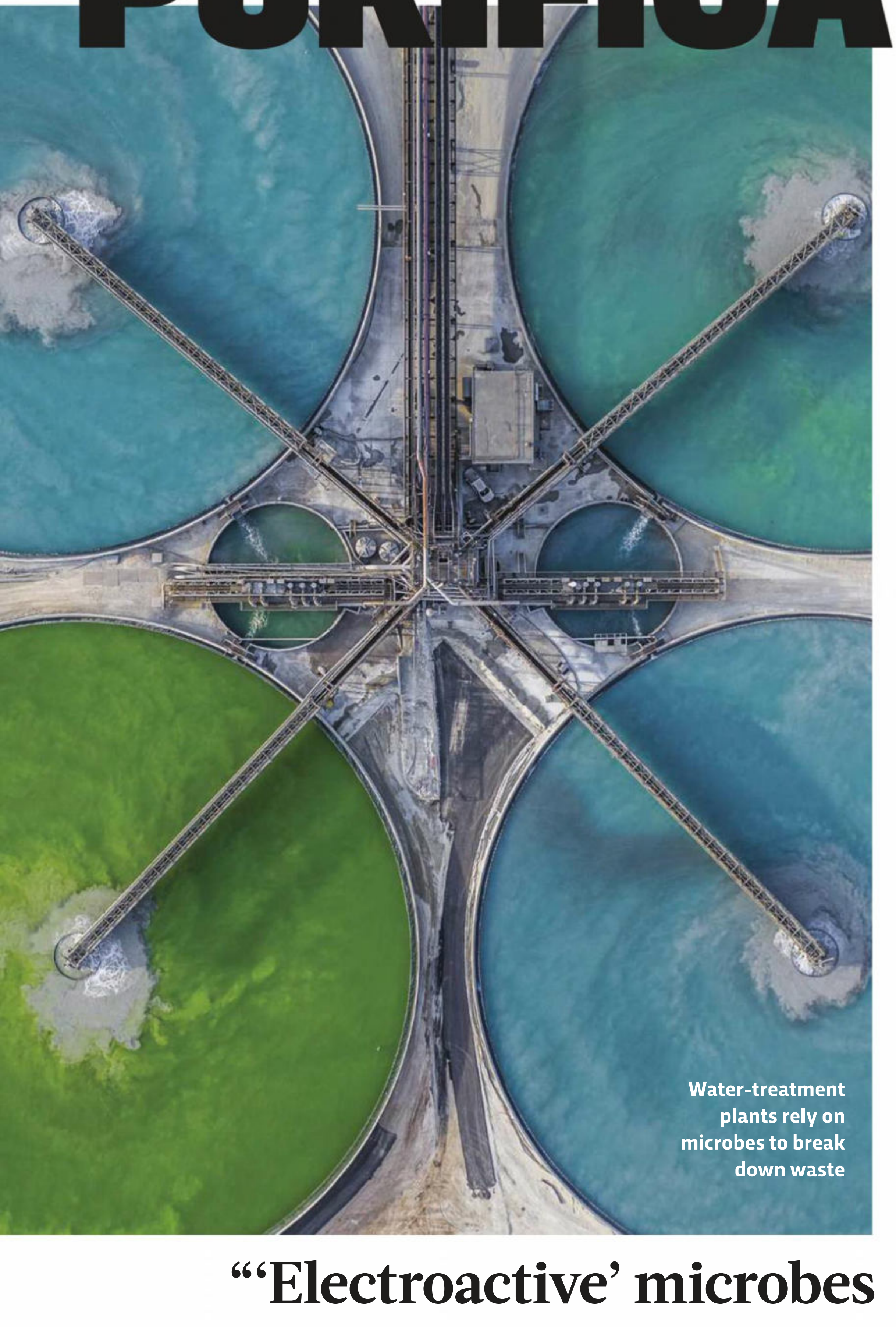
There are several other ways in which bacteria can generate biofuels. One approach involves some unusual species of bacteria that eat and excrete electrons (negatively-charged subatomic particles), generating electricity. Stick an electrode in the ground in the right environment and a colony of these 'electroactive' bacteria will begin to grow around it.

Prof Derek Lovley at the University of Massachusetts and his colleagues have spent several years working out how to use these microbes for renewable energy generation. In 2010, they took *Sporomusa ovata* bacteria and gradually starved them of their preferred 'food' – hydrogen – while also providing them with ample electricity. Eventually, the microbes adapted to feed on the electrons instead of the hydrogen, and then used the electrical energy to convert CO_2 into acetate, a commercially attractive salt that can be turned into biofuels or plastics. Lovley calls the process 'microbial electrosynthesis', and it carries the potential to generate biofuels more efficiently than agriculture can. This is because the electricity to power microbial synthesis can come from solar panels, which are – perhaps surprisingly – a more effective way to capture solar energy than the photosynthetic plants, like rapeseed, currently used to make biofuels.

Earlier this year, Lovley and his colleagues revealed yet another way bacteria can help us produce sustainable energy. Some electroactive bacteria grow tiny electrically-conductive hairs: the researchers plucked off those hairs, sandwiched them between two electrically-conductive gold plates – and discovered the device generates electricity spontaneously. Their 'Air-gen' device pulls electricity directly from the air, apparently taking advantage of differences in humidity in order to do so. Lovley and his team calculated that they could scale up Air-gen devices to outperform today's commercial solar panels – and unlike solar panels, Air-gen would work at night too. ▸

WATER PURIFICATION

Bacteria that feed on dirty water



Water-treatment plants rely on microbes to break down waste

Bacteria are the ultimate recyclers. While humans have traditionally looked on sewage as a waste product, bacteria have always treated it as food. This is why bacteria play a key role in wastewater treatment plants. But running those plants can be expensive: we usually rely on oxygen-consuming microbes to break down the waste, which means wastewater must be kept aerated with air pumps that are costly to operate.

It doesn't have to be that way, says Matthew Silver, co-founder and CEO at Cambrian Innovation in Massachusetts. Cambrian has developed an approach for cleaning industrial wastewater that generates more energy than it consumes. This is possible, says Silver, because industrial wastewater is often full of energy. Wastewater from the dairy industry, for example, can be rich in carbohydrates and proteins. "What we're treating – the complex carbohydrates – is basically like a fuel," he says.

The company's system largely relies on bacteria that can grow in the absence of oxygen, which saves the cost of running air pumps. In one part of the system, 'electroactive' microbes including *Geobacter* and *Shewanella* consume the waste in the water and excrete electrons and other charged particles. Elsewhere in the system, so-called 'methanogenic' bacteria use some of these particles as a source of energy to convert CO_2 into methane gas. "The methane can then be burned to generate heat or electricity," says Silver.

The idea of using microbes to simultaneously treat wastewater and generate power goes back more than 15 years, but going from lab-based demonstrations to a commercially viable system has proved difficult. "The energy density in sewage is low, so the volume you need to process to provide much power is enormous," says Prof Buz Barstow at Cornell University, New York, who researches the potential for bacterial energy generation.

But Silver says the economics become more attractive when the technology is used at industrial sites, because industrial wastewater typically contains a higher volume of energy than municipal sewage.

> "'Electroactive' microbes including *Geobacter* and *Shewanella* consume waste in the water and excrete electrons"

GETTY IMAGES, SCIENCE PHOTO LIBRARY, SOLAR FOODS

FOOD

Protein from thin air?

Bacteria could feed the world. While some bacteria turn CO_2 into valuable fuels, other bacteria – called 'hydrogenotrophs' – can transform CO_2 into proteins suitable for human consumption.

In a sense, this shouldn't come as a great surprise. The plants we eat, or that we feed to livestock, grow because they take energy from the Sun and use it to convert CO_2 into carbohydrates. Strictly speaking, plants didn't evolve this ability to transform CO_2 into food: they gained the skill by incorporating photosynthetic bacteria into their cells.

Solar panels are more effective than photosynthetic organisms at capturing solar energy, and this raises an intriguing possibility. If we can take solar electricity and use it to help bacteria build protein from CO_2, we could grow food more efficiently than ever before.

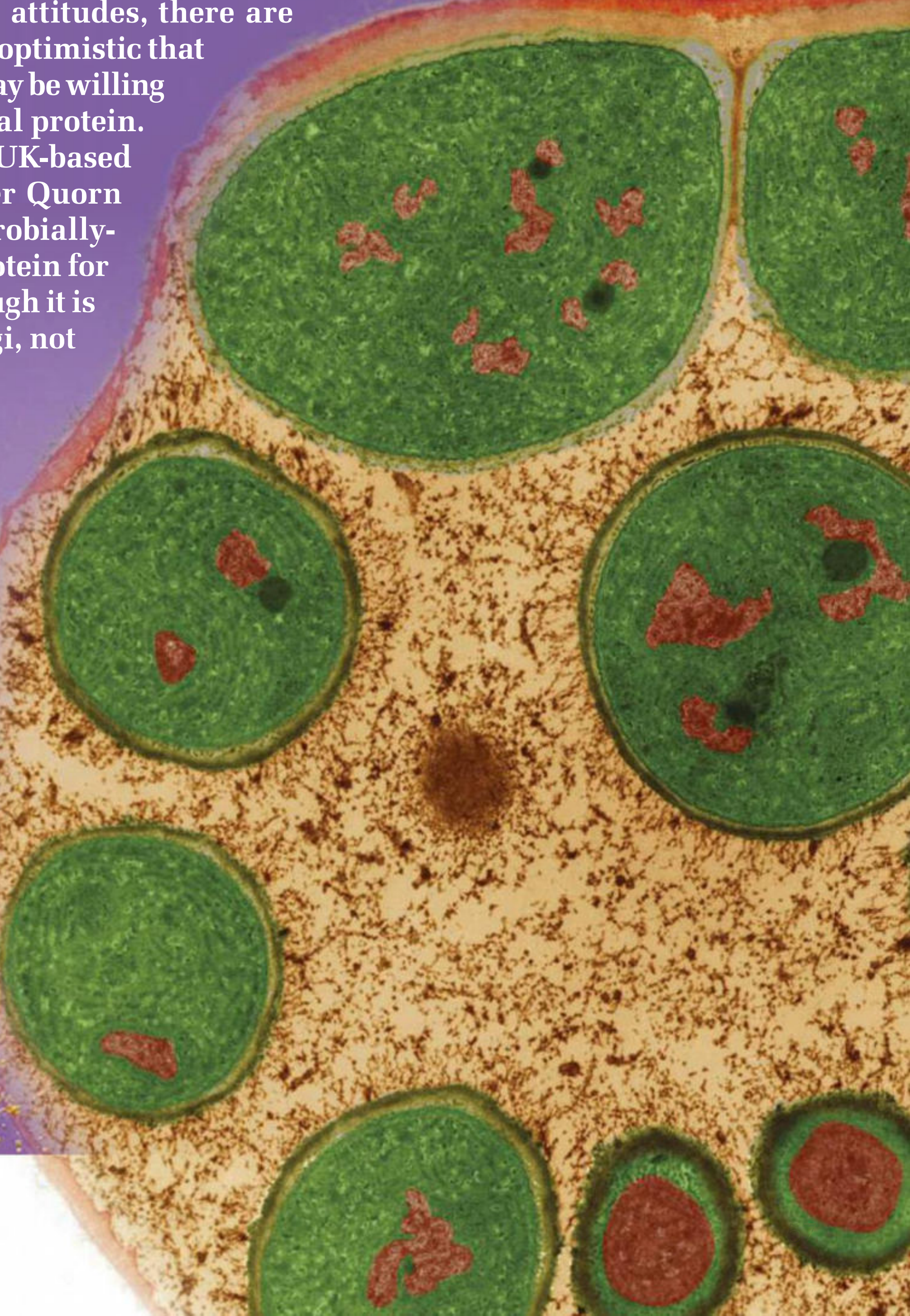
Solar Foods, a Finnish start-up, is one of several companies aiming to commercialise this non-photosynthetic food. Dr Pasi Vainikka, the company's CEO, says the approach involves using power from solar panels to break down water molecules and generate hydrogen gas. Solar Foods then feeds the hydrogen to bacteria growing in a fermenter – for commercial reasons Vainikka prefers not to reveal exactly what species of hydrogenotroph this is. The microbes use this hydrogen as an energy source to turn atmospheric CO_2 into high-quality protein that could replace animal proteins in our diet.

"We are disconnecting food production from agriculture," says Vainikka. Doing so has advantages. For instance, the fermenters that Solar Foods will be using in the coming years don't take up much room. "We are basically operating a brewery," he says. Even allowing for the fact that the fermenters must be hooked up to solar power plants, the total land requirements are still small: Vainikka estimates that Solar Foods could produce a given amount of protein on one-twentieth of the land that a traditional farm requires.

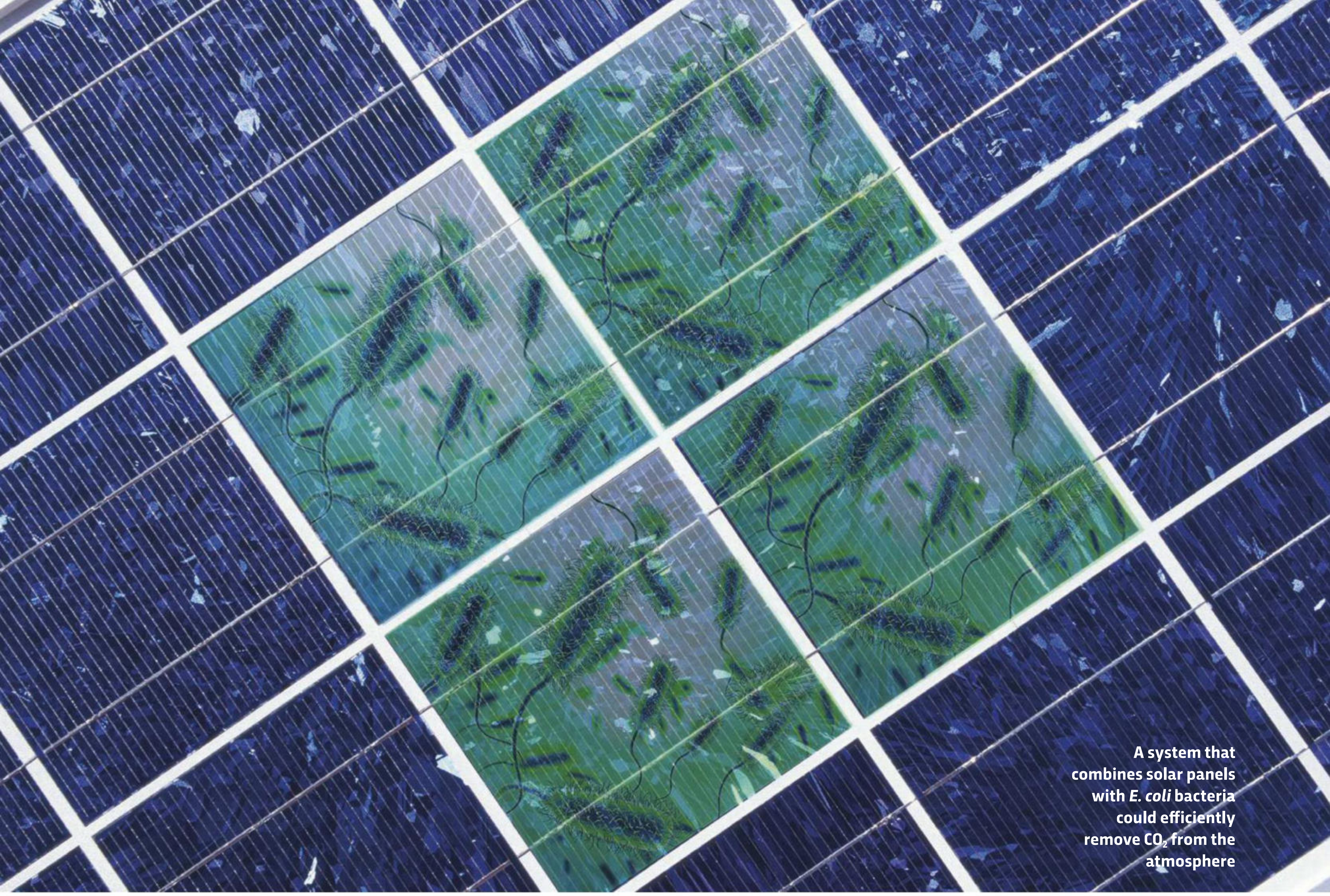
This has the potential to allow some farmland to be converted to forest, which soaks up more CO_2 than farmland does. "On a systemic level, we could be carbon negative," says Vainikka.

Prof Buz Barstow at Cornell University, New York, says that research suggests there's a huge amount of potential for creation of planet-friendly protein using bacteria and other microbes.

Vainikka envisions the Solar Food product as an additive to boost the protein content of foods like bread and pasta, or plant-based drinks such as oat milk. And although the company – and others like it – may sink or swim on consumer attitudes, there are reasons to be optimistic that consumers may be willing to eat bacterial protein. After all, the UK-based manufacturer Quorn has sold microbially-generated protein for years – although it is made by fungi, not bacteria. ▶



Photosynthetic bacteria can use energy from the Sun to transform CO_2 into food



A system that combines solar panels with *E. coli* bacteria could efficiently remove CO_2 from the atmosphere

CLIMATE CHANGE

Gobbling up greenhouse gases

Bacteria may be tiny, but they could have a huge impact in the battle to limit climate change. This is because many species of bacteria will 'eat' CO_2, our principal greenhouse gas. But there is a flaw in this idea: bacteria only munch through CO_2 slowly.

Faster-growing microbe species could remove more CO_2, but those bacteria prefer to eat sugar over CO_2. Last year, however, Prof Ron Milo and his colleagues at the Weizmann Institute of Science, Israel, showed that it was possible to turn a fast-growing microbe – *E. coli* – into a CO_2 consumer.

Milo's team modified *E. coli* by inserting DNA from CO_2-consuming photosynthetic bacteria. Then they put the *E. coli* in an environment with high concentrations of CO_2 and almost no sugar. After about a year, the *E. coli* had evolved to feed off the CO_2.

"Our work provides a proof-of-concept that dramatic changes in the metabolism of commonly-used microbes are attainable within reasonable time scales," says team member Dr Schmuel Gleizer, also at the Weizmann Institute. The *E. coli* gains the power it needs to eat CO_2 from formate, a chemical that can be generated using renewable power from solar panels. In theory, says Gleizer, a solar panel-*E. coli* system could be 10 times more efficient than photosynthesis at removing CO_2 from the atmosphere.

"I honestly think it's a major breakthrough," says Prof Uwe Bornscheuerm, a biotechnologist at the University of Greifswald, Germany, who was not involved in the study. As the research develops, it could have an important positive impact on global warming, he adds.

Other scientists are experimenting with 'probiotics for soil' by injecting the dirt beneath our feet with carefully-selected microbes that both boost the soil's carbon-storage capacity and accelerate the growth rate of crops planted within it. Some researchers claim that, after application of soil probiotics, a hectare of farmland can store an additional 10 tonnes of CO_2. This implies, they say, that the world's agricultural land has the potential to absorb all of the carbon that humanity emits in one year.

But such research is controversial. The problem, according to Dr Adam Frew, an ecologist at the University of Southern Queensland, Australia, is that we don't know enough about the nature of the microbial communities in soil, which makes modifying them in a beneficial way difficult. "There are no simple shortcuts," he says. Microbes may have the power to improve the carbon-storage potential of soil, but a better approach might be to achieve this by nourishing the microbes already living in the dirt rather than adding new ones.

POLLUTION

Cleaning up contamination

Bacteria will eat almost anything that contains carbon. Some microbes have even adapted to munch through oil spills and other forms of pollution. "There were big blooms of bacteria around the Deepwater Horizon oil spill [in the Gulf of Mexico in 2010]," says Prof Gautam Dantas, a microbiologist at Washington University in St Louis, Missouri.

This oil-eating ability has not gone unnoticed: researchers around the world are analysing the bacterial communities in soils near oil spills to identify which species are best at degrading the pollutant. The idea is that blends of these oil-eating microbes could be injected into the dirt anywhere in the world where oil pollution is a significant issue.

A potential problem with this approach is that, as with the soil probiotics for crops, we don't know a lot about the microbial communities within soil. "Microbes added to the soil will probably struggle to compete against the indigenous microbes already there," says Dr Hermann Heipieper at the Helmholtz Centre for Environmental Research, Germany.

But bacteria are still an important component in clean-up operations. The broader point to bear in mind is that microbes have an amazing capacity to evolve and adapt to consume new foods. If the soil around an industrial plant becomes contaminated with oil, chances are that some of the microbes in that soil will begin eating it. We can help them consume their meal more rapidly by providing them with the other nutrients they need to remain healthy – an approach called 'biostimulation'. "This is regularly done by adding nitrogen, phosphorus and iron fertilisers," says Heipieper.

It's also possible to genetically engineer bacteria so that they convert heavy metals, such as mercury, into less toxic forms – but there are ethical and safety concerns about releasing genetically modified organisms into nature. ➤

After the Deepwater Horizon oil spill, pollution-munching bacteria were found in oil slicks, like the one below

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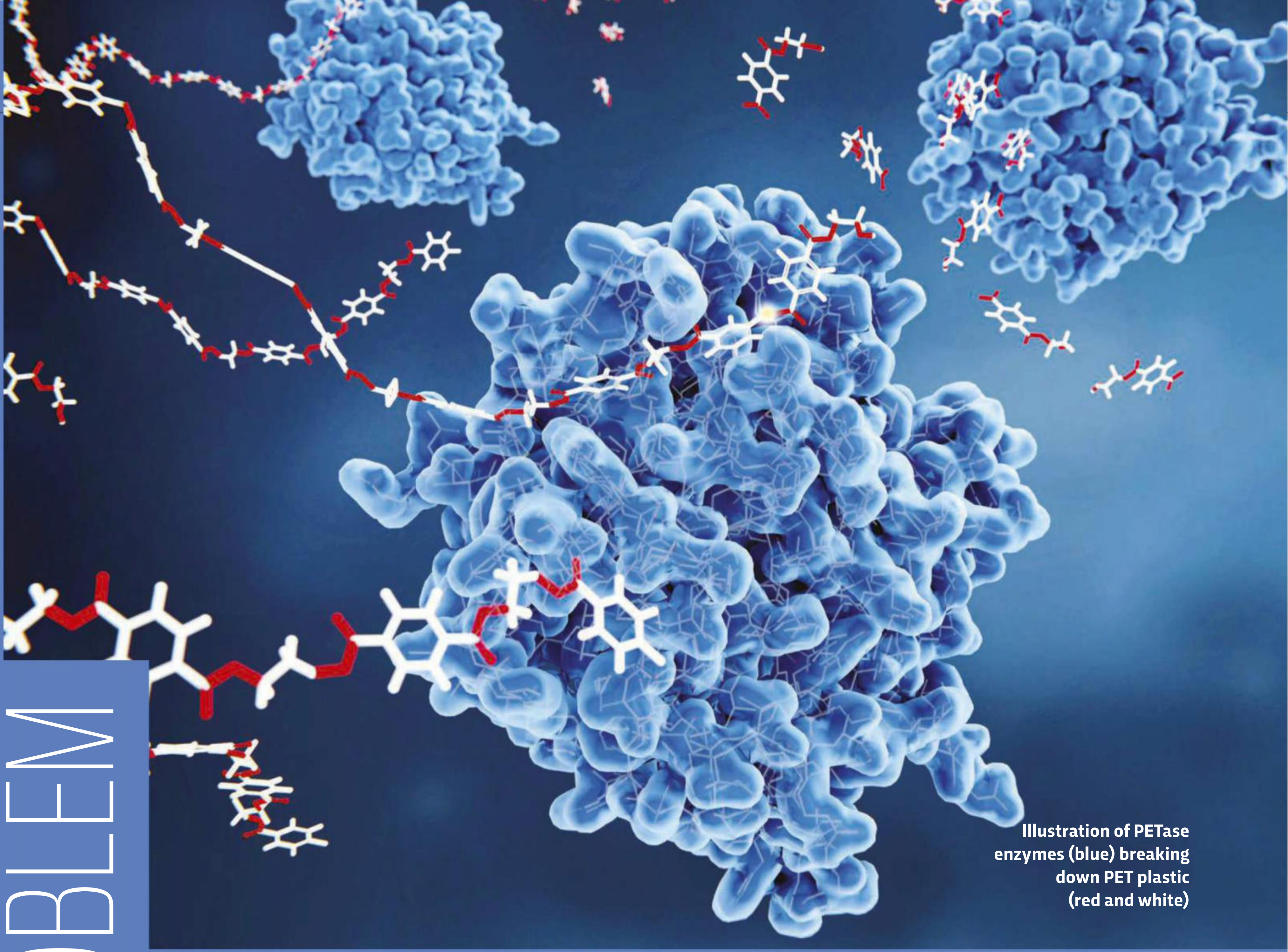


Illustration of PETase enzymes (blue) breaking down PET plastic (red and white)

For some bacteria, plastic is fantastic

Bacteria are not fussy. As well as oil, they'll eat the refined, carbon-containing products that we manufacture from that oil. Like plastic, for example.

In 2016, a team in Japan went to a recycling site and collected samples of the plastic 'polyethylene terephthalate' (PET), which is used to make drinks bottles and the polyester in our clothes. They discovered that, on some of the samples, there were plastic-eating bacteria. The microbes were using a pair of enzymes, dubbed 'PETase' and 'MHETase', to break down the plastic into smaller molecules such as ethylene glycol, which can be recycled to make new plastic. The researchers named the bacteria *Ideonella sakaiensis*.

What makes the discovery all the more astonishing is that PET plastic has been polluting the natural world for no more than 80 years. "It's not long for this bacterium to have evolved [to eat] this novel, man-made carbon source," says Prof Uwe Bornscheuer at the University of Greifswald, Germany.

I. sakaiensis eats plastic in the environment slowly, but biologists can help by isolating the plastic-eating enzymes inside the bacteria and tweaking their structure to make them work more efficiently. In 2018, a team led by Prof John McGeehan at the University of Portsmouth engineered a version of the *I. sakaiensis* PETase enzyme that was almost 20 per cent more efficient at breaking down plastic. They are now trying to discover and engineer other bacterial enzymes that work efficiently enough for commercial use on a range of polluting plastics.

A study published earlier this year suggests success is possible. Researchers at French company Carbios took a bacterial plastic-eating enzyme – LCC – that was isolated from a compost heap about a decade ago, and tweaked its structure in the lab. Normally, the enzyme breaks down PET plastic over the course of several days: the engineered version could do so in a matter of hours. The researchers then used the enzyme to break down waste PET plastic and turned the building blocks they produced into plastic bottles that were identical to 'virgin' bottles created from oil. "This is a great proof-of-principle that enzymes can be engineered to help recycle some of our most polluting plastics," says McGeehan, who was not involved in this study.

It's not just PET plastic that bacteria will eat. Earlier this year, Dr Hermann Heipieper and his team at the Helmholtz Centre for Environmental Research, Germany, found evidence that some bacteria may be able to break down polyurethane, used to make insulation and car parts. "Reports are coming in from all over the world of bacteria that can degrade plastics – it's really exciting," says McGeehan.

ANTIBIOTICS

Can bacteria help undo the damage they created?

It was only in 1928 that Alexander Fleming discovered penicillin, the first antibiotic, and it was such an important finding that we still rely on these bacteria-slaying drugs to stay healthy. But by using (and overusing) antibiotics, we've flooded the environment with them, which has given bacteria ample opportunity to evolve resistance to many of the drugs. Surprisingly, though, bacteria might be able to help us with the very problem they created, because some of them eat antibiotics.

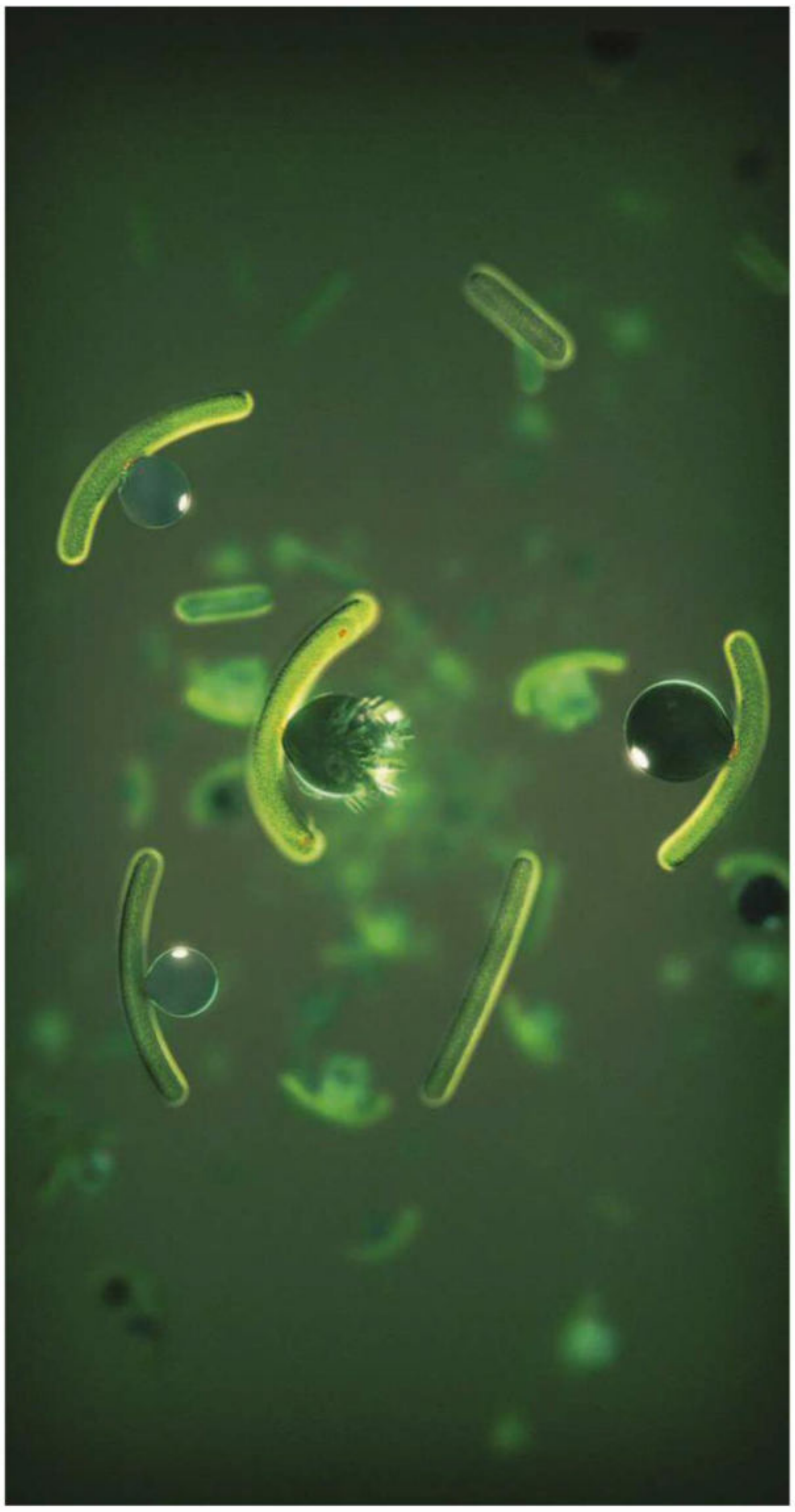
"I've been working on this for a dozen years, but it's still surprising to me that it happens," says Prof Gautam Dantas at Washington University in St Louis, Missouri.

In 2018, Dantas and his colleagues worked out which enzymes help some soil bacteria to eat penicillin. They then transferred the ability into the super-common, mostly harmless, microbe *E. coli*. It's possible that such modified bacteria could eventually be used in wastewater treatment plants to remove antibiotics from the water – although Dantas points out there are significant hurdles to clear before that could happen. Perhaps the greatest problem is that microbes swap DNA with other microbes they meet, so there would be real concerns that antibiotic-eating genes would pass into other bacteria, and ultimately into species that cause dangerous diseases. In that case, the harmful bacteria would have the ability to eat the drugs that are being used to fight them.

But given enough time to work with the bacteria, researchers may well find ways to overcome such obstacles and turn bacteria into a key weapon against antibiotic resistance. The idea won't surprise anyone who is aware of the astonishing potential bacteria have to overcome the many challenges we present them with – from destroying CO_2, plastic and pollution, to creating food, clean water, renewable power and targeted cancer treatments. **SF**

> **"We've flooded the environment with antibiotics, which has given bacteria the opportunity to evolve resistance"**

Illustration of antibiotics (spheres) killing bacteria (rods)



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by **COLIN BARRAS**
Colin is a freelance science writer and editor, based near Ann Arbor, Michigan.

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COMMENT

RETHINKING THE VACCINE

Could genetic material, rather than deactivated viruses, help defeat COVID-19?

Like many others, I am convinced our best hope of defeating this novel coronavirus is by developing a vaccine. So I was delighted, a few months ago, when the BBC series, *Horizon*, asked me to make a film about the vaccine work being carried out by a team from Imperial College, led by Prof Robin Shattock.

Robin told me that when he first heard about a novel virus causing pneumonia, he assumed that it would be contained. But it soon became clear that this outbreak was not going to be stopped. A critical turning point was the publication by Chinese scientists on 10 January of the virus's genome – its genetic blueprint. With that information Robin and his team were able, in just a few weeks, to create a prototype RNA vaccine against it.

The traditional way of creating a vaccine is to use a killed or weakened strain of the virus, or even part of the virus, and use that to provoke the immune system into responding. Once the immune system has mounted an initial response it 'remembers' what the virus looks like and will respond faster the next time it encounters that virus. It's a simple premise, but most vaccines take years to develop and test. The ambition of the Imperial team, and others, is to have a vaccine available by the end of this year.

The Imperial scientists think they can do this because their approach is different. Instead of using bits of the virus for their vaccine, they use lab-grown stretches of genetic material, called RNA, that are identical to the ones the SARS-CoV-2 coronavirus uses to create the club-shaped spikes on its surface.

> **"These so-called 'RNA vaccines' are so new that none has yet been approved for medical use"**

The idea is that once these stretches of genetic material are injected into muscle cells, they will act just like a virus would. They'll hijack the mechanism of the cells and make them churn out viral protein. But instead of producing whole viruses, the cells will only be churning out these club-shaped spikes, which by themselves are not infectious but will hopefully provoke a powerful immune reaction. These so-called 'RNA vaccines' are so new that none has yet been approved for medical use.

They started by testing it on mice, which had a strong antibody response, then moved onto macaques, which unlike mice do get COVID-19. A group of macaques were injected with the vaccine and the plan was to let them develop an antibody response before challenging them with live virus. At the time of writing, we don't know the results, but the plan was, assuming all went well, to start human trials in late June.

What's exciting about the Imperial approach is that if everything goes well – and that is a big if – Robin says they could be able to produce up to five million doses of the vaccine by the end of this year. Enough to protect the more vulnerable against that much-talked-about – and feared – potential second wave of infections. **SF**

MICHAEL MOSLEY
Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* His latest book is *Fast Asleep* (£9.99, Short Books).

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

COMMENT

HITTING THE WALL

Lockdown is tough, but there are ways we can alter our mindset and endure this challenging situation a little more successfully

Lockdown is more of an endurance sport than a sprint, so unless you trained for it, there was a moment when you hit the wall. I was on Week 2.5 when I started wailing like a little kid in front of my kid, lashing out at the doorframe, and was sent to my room by my husband. Not a good look for a grown-up. But emotions, stress and uncertainty are tough things to tackle whatever your age, particularly when the race is already running and the finish line is a moving target.

Dr Nathan Smith is an expert in extreme stress. He spends his research time with people who live on the edge of physical, psychological and social reality – astronauts, polar explorers – people you and I are unlikely to encounter in daily life. But his work at the University of Manchester came in handy when I was at my low ebb during this crisis.

Quarantine, Smith said to me over the phone when he graciously responded to my cry for help, is maddening because human beings like structure. We develop our lives to follow a certain routine. Some people – like me, it turns out – are more fixed than flexible. And when that's disrupted, we lose it. Combine that with a big dose of uncertainty and a feeling of powerlessness, and it's a recipe for self-sabotage.

Most people are terrible at noticing when things are going downhill, Smith explained, but the first signs that there might be a problem is that we stop paying as much attention to ourselves and our belongings as we might otherwise. Out in the field, holes might start appearing in a tent or in a sleeping bag. At home, rubbish might start piling up, or we might stop showering. If there's anyone around us, they might start hearing more negative things coming out of our mouths. It might seem that we've lost optimism and hope. There might be more fights. More tears. More unhelpful vices.

> **"Quarantine is maddening because human beings like structure. We develop our lives to follow a certain routine"**

While we might not be able to control the outside world, we can control our mindset. We can choose how we think about things – acknowledge that there is more than one way to skin a cat. We are still in charge of our thoughts, even if our actions have been locked down. And we can wrestle autonomy back into our lives by setting up a routine that helps us structure our days and give us a sense that we are still in charge of our lives.

Polar explorer Eric Larsen told me that around Day 40 of any big expedition he's been on, he has a moment of release, when he lets go of the old 'normal' and gives in to the new. It's the redemption song to the temper tantrums on the ice, and the routines that help him get through each day but ultimately make his journey monotonous and incredibly arduous. We may not have the same physical demands as Eric, but we can certainly learn from people like him who put themselves in extreme situations. And after this race, I'll be trained up for the next round of whatever the Universe has in store for us… **SF**

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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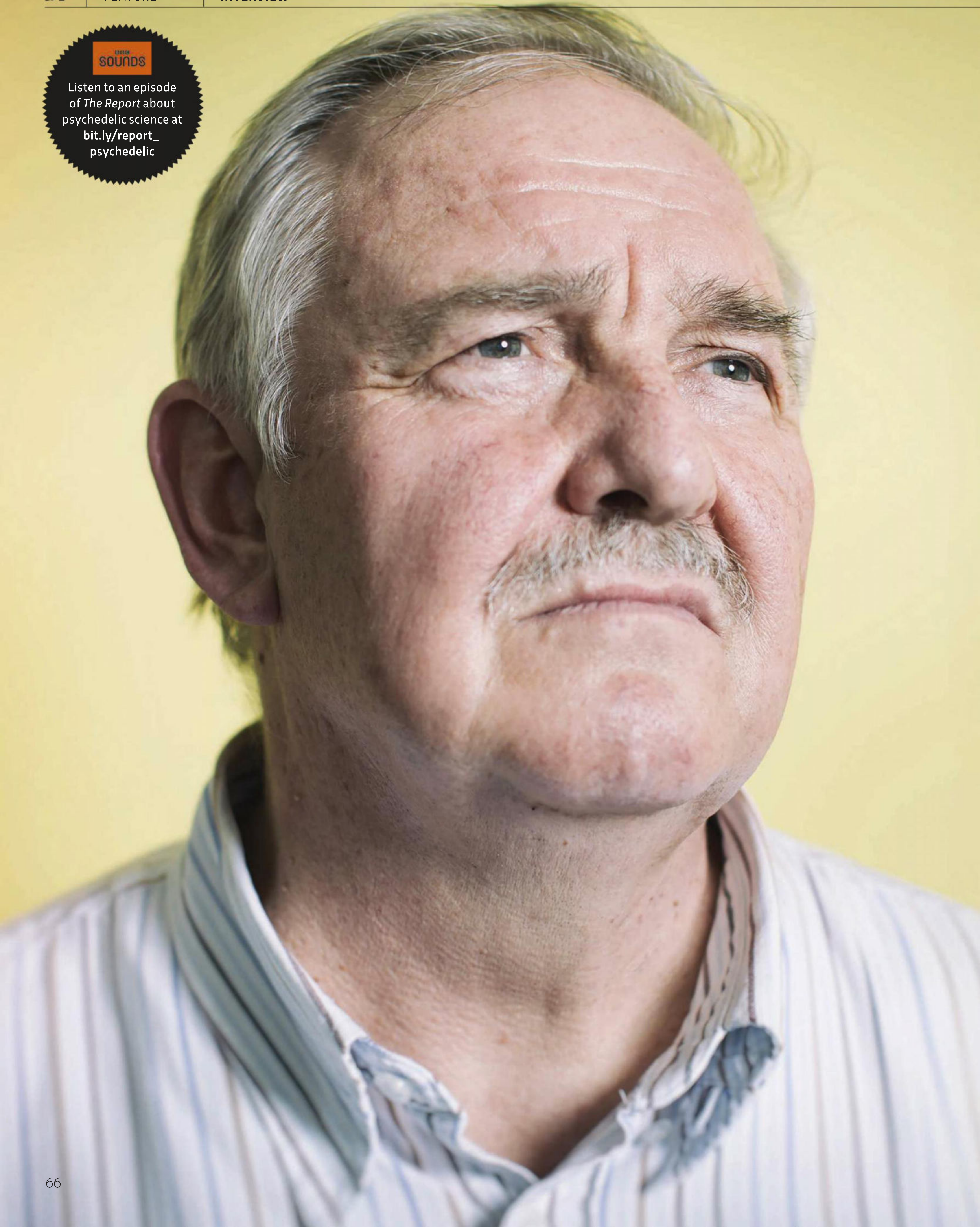

OPENING THE DOORS OF DEPRESSION

For the past decade **Prof David Nutt** has been investigating the therapeutic potential of psychedelic drugs. He spoke to **Jason Goodyer** about his pioneering work on using psilocybin to treat depression and the effect that psychedelics have on other mental disorders

YOUR WORK IS CENTRED ON PSYCHEDELIC DRUGS. WHAT DOES THE TERM 'PSYCHEDELIC' ACTUALLY MEAN?

Psychedelics was a term developed back in the 1950s by people like Aldous Huxley [the author of *The Doors Of Perception*]. Psychedelic means mind-manifesting. Typically, we talk about psychedelic drugs as drugs that produce altered states of perception and consciousness, such as magic mushrooms, LSD, mescaline, peyote, DMT, ayahuasca. It turns out they all work on a particular receptor in the brain called the serotonin 5HT2A receptor.

WHAT IS THE ROLE OF THE SEROTONIN 5HT2A RECEPTOR?

The human brain is loaded with them, all in the parts of the brain where you do your thinking and your analysis of yourself. They tie together your consciousness with your other senses. They're really in that circuit that kind of defines what you are as a human being. When you stimulate those receptors with psychedelics, you change the way the brain processes things.

The brain is an amazing organ; it's the most efficient computer, 10 times more energy efficient than any computer we've yet invented. One of the reasons that the brain is so efficient is that it learns very quickly what to predict. Brains make inferences and we live through those inferences because it's just so much more efficient. If your brain had to update every, say, 15 milliseconds, everything that's gone into it, that would consume enormous amounts of energy. So, the brain basically looks for change. It sees what's there and listens to what's there, and then when things change, it takes notice. The rest of the time, it just says that things haven't changed.

That process is what we call a small world; the brain becomes very efficient at doing what's just enough to make sure you can find your way home and you can do your homework and you can turn on the TV. You can do all the things you need to, but you do them almost in a reflex way. The brain develops these sophisticated habits and psychedelics disrupt those.

CAN YOU GIVE ME AN EXAMPLE?

One of the elegant things about our research – the thing that I find perhaps the most interesting of all – is that, we know from the physiology of the visual system that when people hallucinate under psychedelics, they see what we call geometric patterns. They see squares, they see circles, they see rectangles and they see spirals. And the physics of visual perception tells us that that's actually the first level of visual analysis. What you see is determined by the brain reconstructing electrical impulses from the eye, and it starts off by reconstructing those kinds of images. Actually, what you're seeing under psychedelics is the early working of your visual system, because the higher work in putting it all together into images has actually been disrupted.

Beyond that, one of the most common positive experiences of people under psychedelics is that they see the world differently. They get insights into their own behaviour – particularly their own behaviour but also into other people's behaviour – which they didn't get before, and they kind of understand things [better]. Those insights can ▶

> "The brain is an amazing organ; it's the most efficient computer, 10 times more energy efficient than any computer we've yet invented"

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▶ be profound and people can change as a result – change their whole behaviour; change their way of life.

HOW DID YOU BEGIN YOUR WORK ON PSYCHEDELICS AND DEPRESSION?

The depression trial was driven in part by the brain imaging studies we did. When we started working with psychedelics, we had no inkling whatsoever that we would be studying psychiatric disorders. We were studying them [the drugs] because they needed to be studied. No one else has studied them, because they've been illegal for 50 years. We were interested to know why they produced these really remarkable effects – both in terms of perceptions and hallucinations, but also the altered sense of self.

So, we started off doing neuroscience. And when we did the first imaging studies, we discovered some rather unexpected things.

The first was that even when you give [magic] mushrooms to people in a scanner, they often come out and say, "Wow! That was an interesting experience," and they often say, "I feel better." People would come back to us a week later saying, "It's amazing, ever since you gave that to me in the scanner, the world seems like a better, brighter, nicer place."

The second thing we noticed was that the parts of the brain that normally drive depression got switched off by psilocybin. So, we thought, well, that's interesting, maybe this wellness feeling that people have has got something to do with switching off the negative mood.

And the third thing that happened was that there was some brain imaging data on depression coming out, suggesting that depression was an over-engagement. There's a circuit in the brain, which is the circuit of the self, that gets over engaged. It's called the default mode network. It's that internal network where you do your thinking about yourself. We noticed that psilocybin completely disrupted that network – it switched it off. And of course, that explains something that's fundamental in psychedelics: the dissolution of the ego.

Many of our subjects in the scanner would describe their body slowly disintegrating and their atoms floating out. They'd float out beyond the scanner and then float into space, and some would go into other dimensions and some would go into mountains and see God. You know, they would be somewhere else other than the scanner.

That sense of disorganisation of where you are in space we can explain now in terms of the brain's circuits. It's because you've disrupted the default mode, which essentially anchors you in normal space. Now, when we discovered that this other group had shown that the default mode network was overactive in depression, we put two and two together and thought, well, if it's overactive in depression and we can disrupt it completely – that's what psychedelics do – maybe we should be trying it in depression.

HOW DID YOU SET UP YOUR EXPERIMENTS?

Depression is the largest cause of disability in the western world, in Britain certainly. Current

PROF DAVID NUTT

David is the Edmond J Safra Professor of Neuropsychopharmacology at Imperial College London. He trained as a medic at Cambridge University and went on to study psychiatry at Oxford University. In 1988 he established the Psychopharmacology Unit in Bristol University before joining Imperial College London in 2008. He is currently Chair of DrugScience and President of the European Brain Council. He was a member and then Chair of the Advisory Committee on the Misuse of Drugs (1998-2009) and served as the medical expert on the Independent Inquiry into the Misuse of Drugs Act. He has published over 400 research paper and 27 books.

"Many of our subjects would describe their body slowly disintegrating and their atoms floating out"

treatments are, you know, they're not bad but they're not brilliant. A lot of people have residual depression and a lot of people have resistant depression. They don't get completely well when they're treated. So, there was a call put out and we argued the case I just told you – that there are three reasons for trying psychedelics in depression – and we got funded.

Actually, that was the easy bit. It was extremely difficult to get permission to do this study. Ethics committees were very cynical.

It took us years to get hold of the drug because we had to get it made and imported from overseas. And they would only allow us to study people with what we call 'treatment-resistant depression', so people who had failed on at least two treatments – two drug treatments – and also had failed on cognitive behaviour therapy (CBT). It turned out some people had failed on 15 or 20 or more different drugs.

It was a simple trial. We gave people a low dose to make sure there was no paradoxical reaction in depressed people to psilocybin, and then we gave them a decent dose, a 25mg dose, which gave them a decent trip. And then we looked to see what happened.

I think it's important to say one other thing. When this was done, there were two therapists with the each person all the way through the trip. We prepared them carefully for what might happen, the good effects and potentially the negative effects of the trip. And then the next day, we did what's called an integration session, which is where the therapists try to help the person make sense of what they've experienced. Because often with depression people have had quite nasty experiences [while tripping]. They relive traumas that they've been trying to repress, and those traumas are in their brain and they're eating away and causing the depression. But then, very often, they made sense of why they were depressed, and then they had to deal with that.

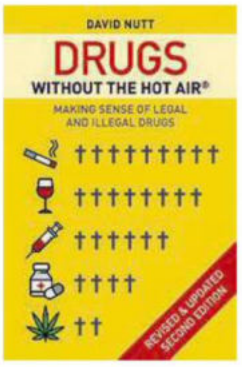
In the trip it's difficult to deal with it; you get insights, but afterwards you need to talk through what they mean with the therapists. We found that from almost the next day, their mood was improved and most people had a benefit for several weeks or months. In fact, even at six months, there was a significant positive impact of this treatment, after just a single dose for most people.

WARNING

Psychedelic drugs are a Class A drug according to UK law. Anyone caught in possession of such substances will face up to seven years in prison, an unlimited fine, or both. Info and support for those affected by substance abuse problems can be found at **bit.ly/drug_support**

DISCOVER MORE

READ *David Nutt's latest book,* Drugs Without The Hot Air: Making Sense Of Legal And Illegal Drugs *(£18.99, UIT Cambridge).*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COULD THIS EFFECT ALSO BE POTENTIALLY USED TO TREAT ADDICTION?

This is where our research is at present. So, what pulls all these things together? It's what we call internalising disorders – addiction, depression, anorexia and also obsessive-compulsive disorder (OCD). These are disorders where people are engaged internally with thinking that's not useful. In depression, people are thinking about things they've done wrong; in OCD they're thinking about contamination; in anorexia they're obsessed with food and weight; and in addiction, they're obsessed with alcohol or tobacco or heroin.

This point I was making about the brain being very efficient, one of the reasons the brain is efficient is that it lays down habits. Think about riding a bike. You start off and my goodness, you're using probably every bit of your brain to balance and to see where you're going and to work out you've got to hold this and push that pedal. It's an enormous amount of conscious effort. But then, after a few days, it's nothing at all. And then for the rest of your life, you can ride bikes. Why? Because your brain has downloaded all the conscious efforts into a habit, a behaviour that is fully acquired and in fact, it's almost impossible then not to ride a bike when you're put on a bike. So, that process of making the brain do its own thing free from conscious control is fabulous for most of life and very necessary.

But suppose your brain gets you locked into something that isn't useful, such as drinking too much or taking heroin. Then it's difficult to unlock that, because the brain is about locking you in. So, what we're hoping is that psychedelics can, by fragmenting that ongoing, habitual process of behaviour and thinking, free people up enough so that they can escape from the addictions. **SF**

FLIGHT OF THE NAVIGATOR

In a space exploration first, NASA is preparing to deploy a chopper on the Red Planet. Flying in a fraction of Earth's gravity, it should be a sight to behold…

by **DR PAUL PARSONS**

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"FLYING IN THE ALIEN ATMOSPHERE OF ANOTHER WORLD IS A FEAT THAT POSES A UNIQUE SET OF ENGINEERING CHALLENGES"

Whether disrupting air traffic, returning glorious vistas of Earth from above, or just spying on the neighbours (if that's your thing), drones have become a familiar sight in our skies. Now, for the first time, the US space agency NASA is poised to fly a drone-like helicopter in the atmosphere of another planet.

The craft, named Ingenuity, will hitch a ride to the Red Planet aboard the one-tonne Perseverance lander, NASA's latest wheeled robotic rover mission to drive across the planet's rugged surface. Perseverance will launch from Earth this summer, with touchdown on Mars scheduled for 18 February 2021.

Flying in the alien atmosphere of another world is a feat that poses a unique set of engineering challenges and yet, if this small technology test mission is successful, it will furnish scientists with a new and highly effective way to explore the planets and moons of our Solar System. That's because flying is a much faster way to get around than ground roving. Aircraft can gather aerial imagery that's much sharper than pictures returned by spacecraft. They can also serve as scouts to identify potential targets for ground-based rover vehicles, and they can even gather samples and bring them back to a central lander station for analysis.

And, of course, they can go where other probes simply can't.

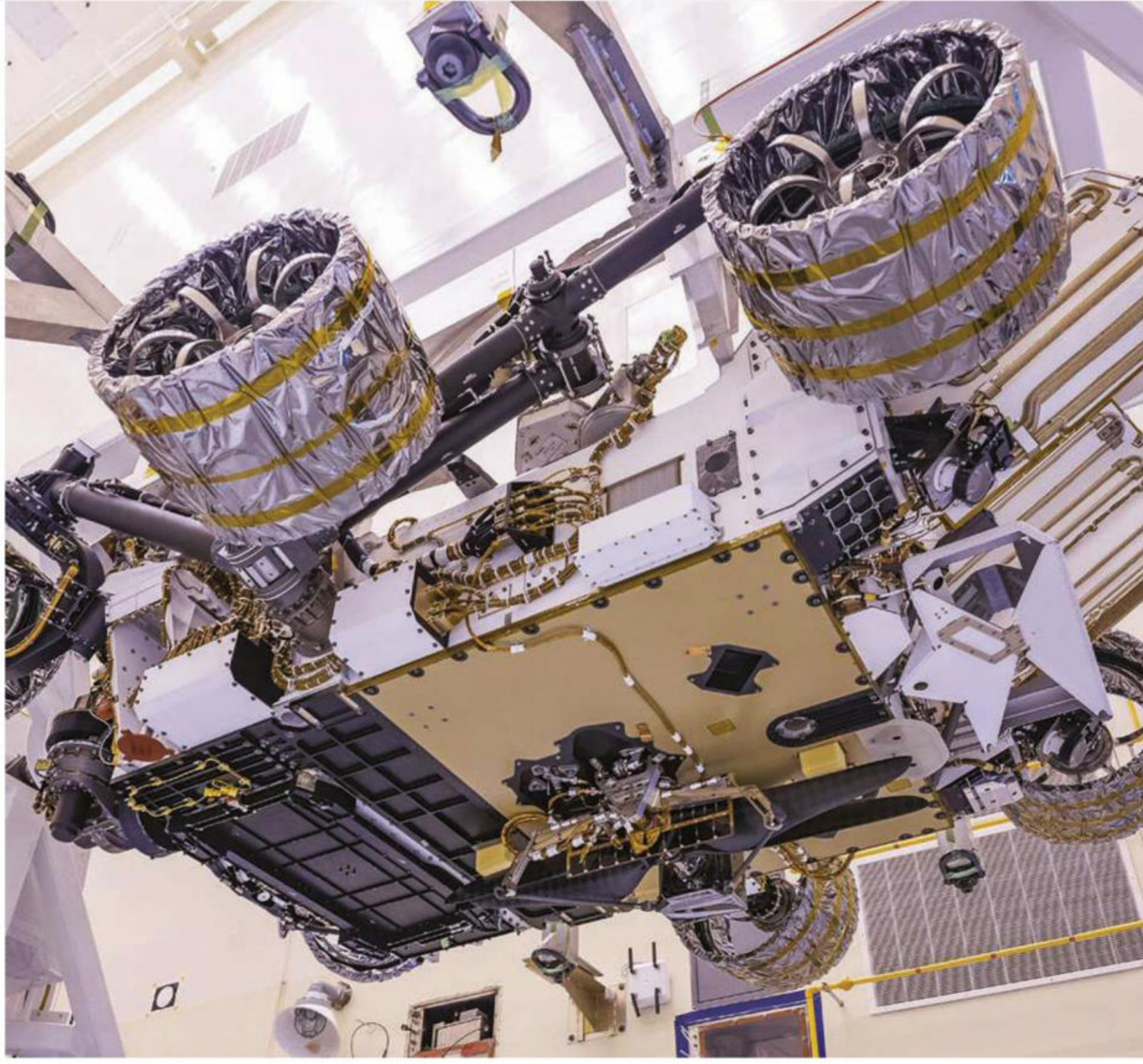
"Larger Mars rotorcraft in the 5kg to 20kg class with small science payloads could access areas not reachable by rovers, and support wide-area surveys in shorter times," says Dr Bob Balaram, Ingenuity's chief engineer, based at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. "There is also a NASA mission to explore Saturn's moon Titan with a flying lander that will arrive in the early 2030s."

The Ingenuity craft is 50 centimetres high with four blades – one pair above the other – mounted on twin, counter-rotating rotors each spanning 1.2 metres. The size of the rotors (which need to be this big for the helicopter to fly in Mars's thin atmosphere) is the main reason why a more familiar drone-like quadcopter design was rejected – such a vehicle would be simply too large to fit on the rover.

Ingenuity is stowed beneath the body of Perseverance, from where it will be dropped onto the surface of Mars, probably a couple of months into the mission. The rover will then drive 100 metres away, to minimise collision risk, and the two will exchange radio signals to 'pair up' – a bit like pairing wireless earbuds to your phone – before the rover sends the command for Ingenuity to make its inaugural flight. This will likely be what Balaram calls a 'mutual selfie' – the two vehicles taking pictures of one another as the helicopter rises to a low hover and then lands again.

MARS EXPLORER

Ingenuity carries a black-and-white navigation camera and a 4,208 x 3,120-pixel colour camera, comparable to what might be found in a mobile phone. Images are beamed by short-range radio link to Perseverance, which then relays them to one of a number of NASA spacecraft in Mars orbit, from where they are transmitted back to Earth. "Multiple images may be stitched into a panorama at some point using ground software tools," says Balaram.



Ingenuity, visible lower centre, attached to the Perseverance rover

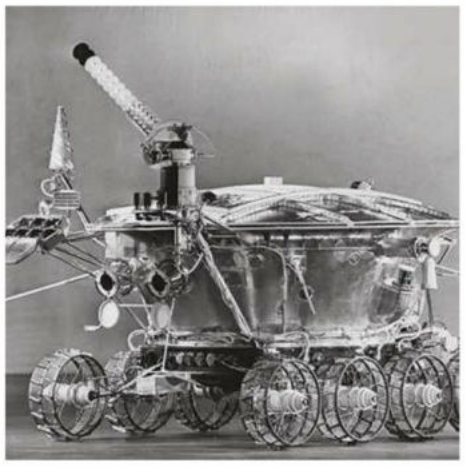
The helicopter isn't going to make any actual scientific observations, however. Instead, the focus is to return engineering data from the test flights that will, it's hoped, validate the technology or at the very least provide valuable feedback to refine future designs.

The primary mission plan is for up to five flights over a period of 30 days, though this may be extended. The maximum horizontal range of the flights will be about 300 metres with a ceiling altitude of 10 metres and a max flight time of 90 seconds, after which the helicopter's six lithium-ion batteries need recharging. This is handled by a solar panel mounted directly above the rotor blades. A full charge takes a whole Martian day ▶

Land, sea and air *All-terrain exploration of the Solar System*

Lunokhod

The first wheeled rover to explore the surface of another world was the Soviet Lunokhod 1 probe, which landed in the Moon's Sea of Rains on 17 November 1970. Resembling a bathtub on wheels, its instruments included cameras and radiation detectors. It survived on the lunar surface for 322 days.



Vega

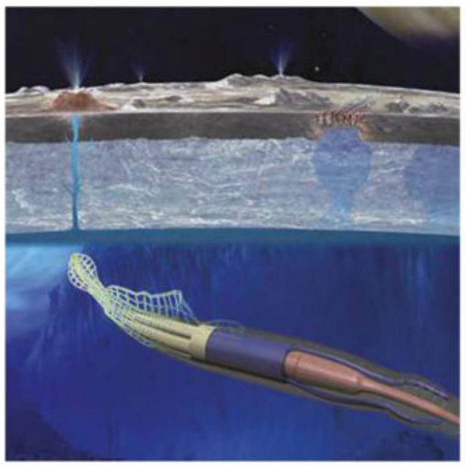
The helium-filled Vega balloons, each measuring 3.5 metres across, were two unpowered aircraft dropped into the atmosphere of Venus by the Soviet Union in 1985. They floated 50km above the planet for 46 hours before they succumbed to the corrosive atmosphere and their failing batteries.

Dragonfly

Due to leave Earth in 2026, NASA's Dragonfly is an octocopter drone that will drop into the skies of Saturn's largest moon, Titan, in 2034. With a nuclear battery on board, it will spend nearly three years surveying Titan, where conditions may resemble those in which life first emerged on Earth.

Europa submarine

There is good evidence that Jupiter's moon Europa harbours an ocean of liquid water beneath its icy surface, heated by the constant flexing of Jupiter's gravitational pull. Some engineers have come up with designs for submersibles to explore this ocean, although none have yet been selected to fly.



NASA/JPL, MASON PECK/CORNELL UNIVERSITY, NASA/GSFC/ARIZONA STATE UNIVERSITY, GEOFFREY LANDIS/WIKIPEDIA

Testing Ingenuity in the lab

to complete, and two-thirds of the power stored is needed to keep the aircraft's electronics warm during the bitterly cold Martian night, when temperatures can plunge to -100°C.

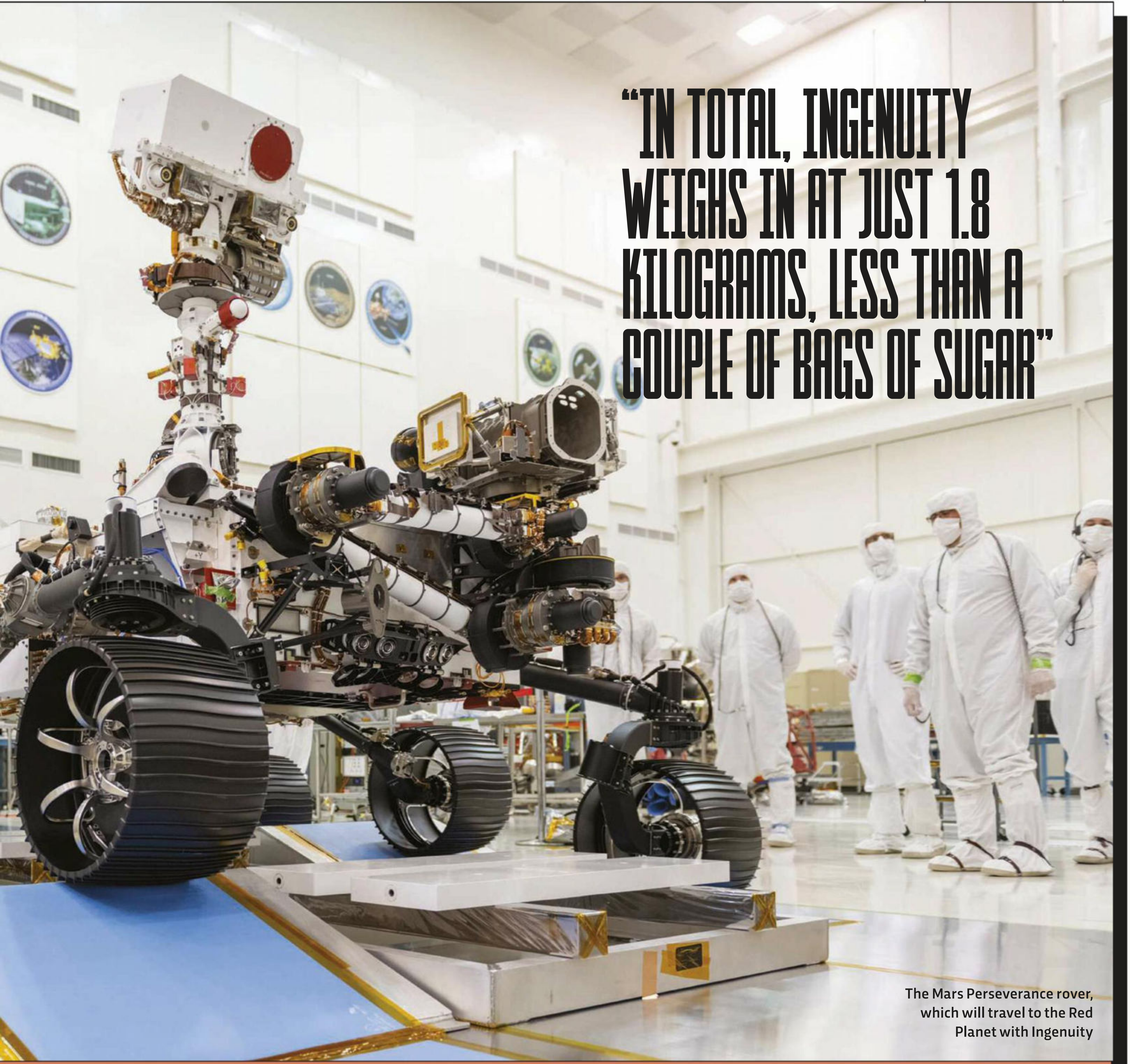
The low temperature is only the beginning of the problems facing a would-be Martian aviator. Aircraft take off using 'lift', an upward force created as air passes over a curved aerofoil. On a plane, the aerofoil is the wing; on a helicopter, it's the rotor blades. But the surface density of Mars's atmosphere is just 1 per cent of Earth's. A cubic metre of air at sea level on Earth weighs 1.2kg, but on Mars that figure drops to just a few grams – roughly equivalent to the tenuous atmosphere on Earth at an altitude of 30,000 metres (100,000 feet). And to generate enough lift to fly from such thin air means the engine has to work overtime. Whereas helicopters on Earth typically spin their blades at 500 revolutions per minute (rpm), on Mars you need to crank this up to around 2,500rpm.

For the same reason, the weight of the craft is kept to an absolute bare minimum. For example, each pair of rotor blades weighs just 56 grams – despite measuring over a metre in length. "Carbon composite layups within a foam core matrix were used to achieve lightweight but stiff blades," says Balaram. In total, Ingenuity weighs in at just 1.8 kilograms, less than a couple of bags of sugar. Balaram has even worked out the best time of day to fly the helicopter on Mars – mid-morning, as it turns out, roughly 11am. By this time, the craft has been

NASA/KSC, NASA/JPL

MARS ROCKS, PERSEVERANCE ROLLS

The new rover mission set to revolutionise the hunt for past life on Mars

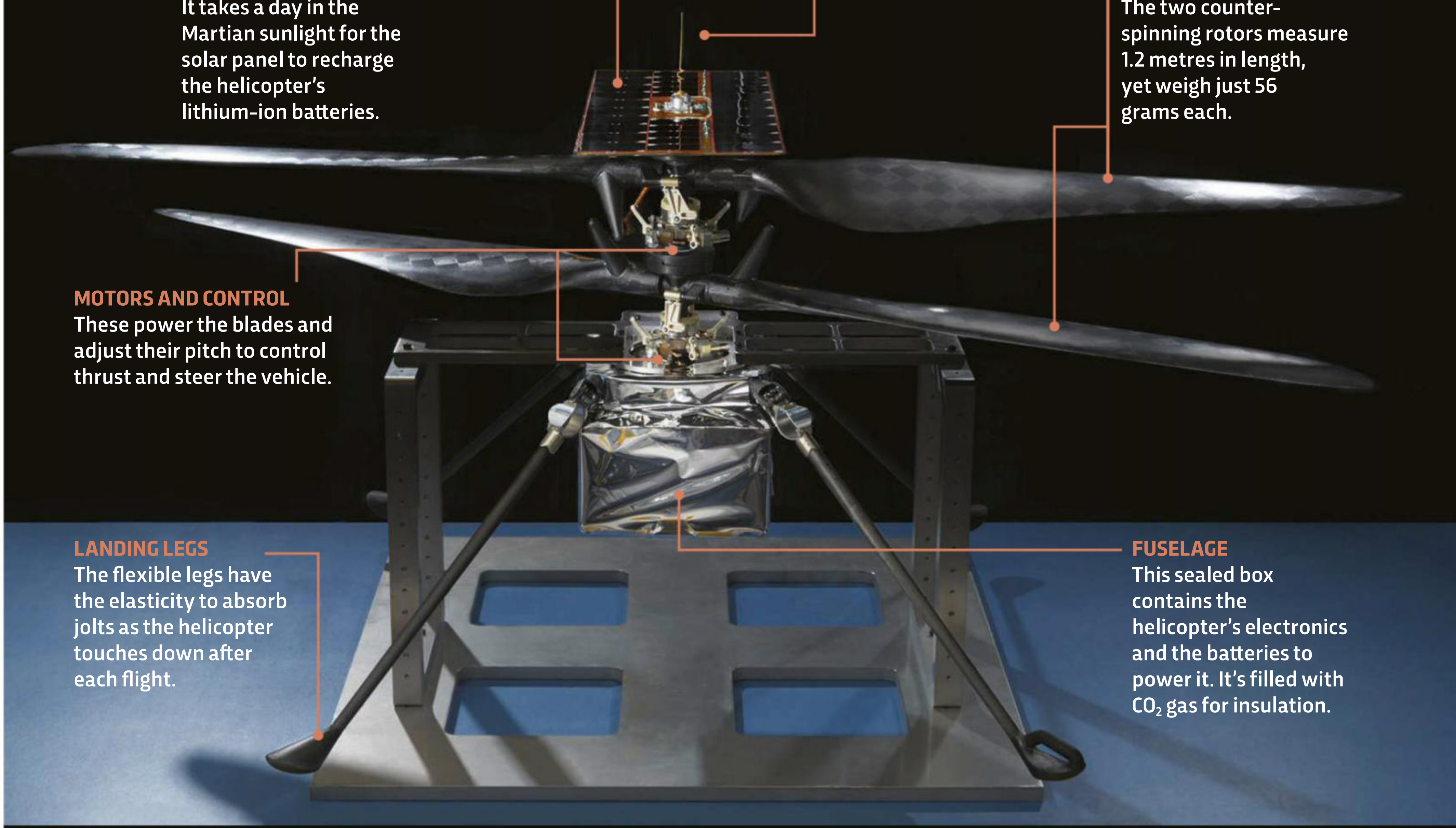


“IN TOTAL, INGENUITY WEIGHS IN AT JUST 1.8 KILOGRAMS, LESS THAN A COUPLE OF BAGS OF SUGAR”

The Mars Perseverance rover, which will travel to the Red Planet with Ingenuity

Ingenuity will fly to the Red Planet with NASA’s Perseverance rover mission. It is scheduled to blast off from Cape Canaveral aboard an Atlas V rocket in a three-week launch window, beginning on 17 July 2020. The one-tonne wheeled vehicle, which is about the size of a small car, is due to touch down in Mars’s Jezero Crater during February 2021. Although Mars is a dry, barren world today, between 3.5 and 4 billion years ago, it is suspected to have enjoyed a warm, wet climate suitable for fostering life. The Jezero Crater landing site is believed to have been the floor of a great lake at this time, awash with liquid water, and Perseverance will scour the site for any remaining biological signatures. The initial mission span is one Martian year (about 1.9 Earth years), during which Perseverance is expected to drive around 200 metres a day, examining soil and rocks. The rover is equipped with a coring drill which it’ll use to extract rock samples, leaving them in canisters along its route for recovery by a future sample return mission.

HOW IT WORKS
INGENUITY



ANTENNA
The radio antenna receives communications from, and returns images and data to, the Perseverance rover.

SOLAR PANEL
It takes a day in the Martian sunlight for the solar panel to recharge the helicopter's lithium-ion batteries.

ROTOR BLADES
The two counter-spinning rotors measure 1.2 metres in length, yet weigh just 56 grams each.

MOTORS AND CONTROL
These power the blades and adjust their pitch to control thrust and steer the vehicle.

LANDING LEGS
The flexible legs have the elasticity to absorb jolts as the helicopter touches down after each flight.

FUSELAGE
This sealed box contains the helicopter's electronics and the batteries to power it. It's filled with CO_2 gas for insulation.

SPECIFICATIONS

MASS: 1.8kg
HEIGHT: 50cm
ROTOR SPAN: 1.2m
ROTOR SPEED: 2,300-2,900rpm

MAX ALTITUDE: 10m
BATTERIES:
6x Sony Li-ion, delivering 220W power

MAX FLIGHT TIME: 90s
RANGE PER FLIGHT: 300m
MAX FLIGHTS PER DAY: 1
MISSION DURATION: 30 days

> “IF THE HELICOPTER’S TRIALS ON MARS ARE A SUCCESS, THEN IT WILL BE A GENUINELY HISTORIC ACHIEVEMENT – THE FIRST EVER POWERED FLIGHT BEYOND EARTH”

warmed by the Sun after the chilly Martian night, but the air is cool, keeping its density as high as possible and its wind speeds low, while the batteries still have a healthy charge. “After we get the first couple of flights under our belt, I’m sure we will try to fly in the afternoon, and do more exploratory things, but the most conservative thing we can do is to pick a mid-morning flight,” he says.

ON TRIAL

The team tested their design inside the JPL’s Space Simulation Chamber, a 25-metre-high, eight-metre-wide cylindrical test vessel in which the atmosphere could be precisely tuned to replicate the aerodynamic conditions on Mars. However, the low pressure was only one of the peculiarities of flying on Mars that had to be modelled. They still needed to account for the planet’s gravity, which is only 0.38 (just over a third) of that found on Earth. They came up with a novel solution.

“A gravity off-load device was installed into the chamber and was used to provide a compensating force on the vehicle to account for the difference in gravity between Earth and Mars,” says Balaram. This literally means attaching a lightweight thread to the top of the vehicle, which they pulled tight just enough to lift 0.62 of the helicopter’s weight on Earth – leaving the remaining 0.38 (its weight on Mars) to be lifted aerodynamically by the rotors.

As well as demonstrating the basic feasibility of flight on Mars, these ground tests were crucial for another reason – allowing the team to fine-tune the Guidance, Navigation and Control (GNC) software that will actually have to pilot the helicopter on Mars. When the first real Martian flights begin, the light-travel time from Earth to Mars will be many minutes, making it impossible for controllers to steer the craft remotely.

Instead, the commands from ground control on Earth consist of a set of waypoints – coordinates selected by controllers – which the GNC software will follow while taking account of the stream of real-time data flooding in from the helicopter’s sensors. These include gyroscopes, accelerometers, a navigation camera, an altimeter, and an inclinometer which measures the aircraft’s tilt.

“Waypoints consist of an x-y position, a height above ground, a vehicle heading, and a desired time to arrive at each point,” Balaram says. To test the software, his team even set up multiple high-energy lamps inside the simulator to recreate sunlight illumination at the Martian surface, as well as fans to simulate flight in windy conditions. On top of all this, Ingenuity must also be a spacecraft, certified to survive the stresses of launch, the seven-month journey to Mars during which it will be subjected to radiation and the harsh vacuum of interplanetary space, and then finally wracked by the high g-forces and scorching 2,200°C heat of entry, descent and landing through Mars’s atmosphere.

But if it works and the helicopter’s trials on Mars are a success, then it will be a genuinely historic achievement – the first-ever powered flight beyond Earth. And the expertise gained will lay the groundwork to fly bigger and better aircraft, capable of carrying a full payload of scientific instruments to explore the skies of distant worlds.

As Balaram puts it: “It’s kind of a Wright Brothers’ moment on another planet.” SF

by **DR PAUL PARSONS** *(@NasaProPlus)*

Paul is a science journalist and author. His book, Ten Short Lessons In Space Travel, *will be published in June (£9.99, Michael O’Mara Books).*

NASA/JPL

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Q&A

YOUR QUESTIONS ANSWERED

... WHAT'S THE LARGEST FLYING ANIMAL?
... WHY DOES LIGHT TRAVEL FASTER THAN SOUND?
... WHAT DID DINOSAURS EVOLVE FROM?
... WILL A CURRY BRING ON LABOUR?
... HOW CAN I PROTECT MYSELF FROM THE CORONAVIRUS WHILE SHOPPING?
... WHY DO DOGS GO ROUND IN CIRCLES BEFORE THEY POO?
... WHY DO LOCUSTS SWARM?
... WHERE DOES SOIL COME FROM?
... IS IT POSSIBLE TO HAVE NO SENSE OF SMELL?

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Shopping List
Liver
Chianti
Fava Bea

ILLUSTRATION: DANIEL BRIGHT

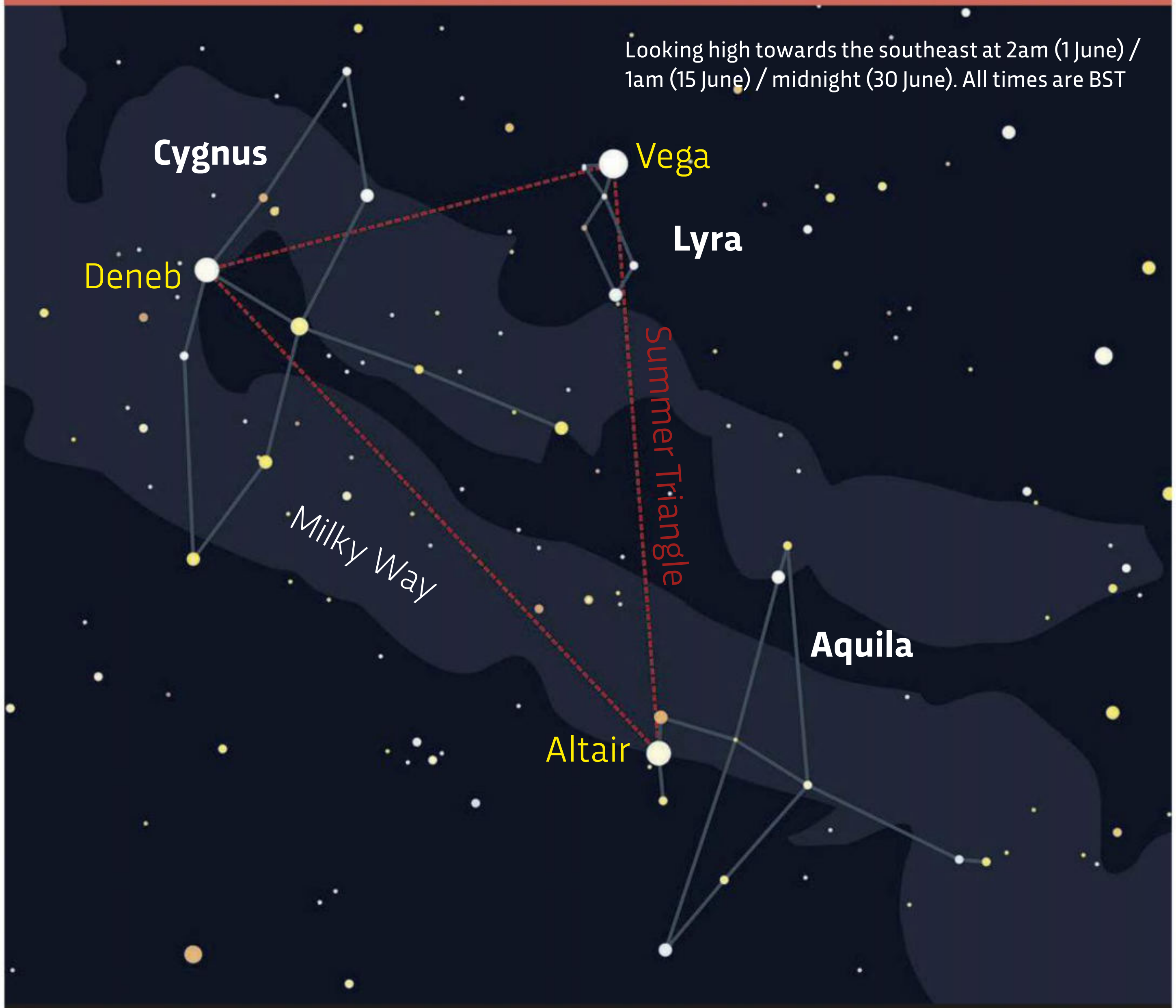
ERICA REYNOLDS, COVENTRY

IS THERE ANY LINK BETWEEN HANDWRITING AND PERSONALITY?

I remember as a child being discouraged from allowing my handwriting to slope backwards – I was warned my relaxed letters would be taken as a sign of an idle personality. Handwriting analysis, or 'graphology', which has its modern roots in the theories espoused by a group of 19th-Century French Catholic clergy, makes many such claims about what is revealed by a person's writing style, some more eyebrow-raising than others. If you have low-hanging, bulbous loops on your 'y's and 'g's, for instance, this is apparently a sign of your sexual prowess. Unsurprisingly, perhaps, contemporary psychology views graphology as a joke – indeed, the claim that our handwriting reveals our personality traits is listed in *50 Great Myths Of Popular Psychology*, an influential book written by a team of US psychologists.

That said, specific claims linking aspects of handwriting to personality continue to emerge, even in mainstream psychology journals. For example, in a 2016 study carried out by researchers in Uruguay, hundreds of people completed personality tests and then signed their name. The researchers reported that, among men, a larger signature correlated with having more social bravado, while in women, a bigger signature correlated with having narcissistic traits. So there might be some very specific situations in which the way you write can be revealing. The Uruguayan researchers suggest that signatures are a special case because they serve as a form of self-expression. ***CJ***

ASTRONOMY FOR BEGINNERS



Looking high towards the southeast at 2am (1 June) / 1am (15 June) / midnight (30 June). All times are BST

HOW DO I FIND THE SUMMER TRIANGLE?

WHEN: JUNE, JULY AND AUGUST; NORTHERN HEMISPHERE

When people think about stargazing, they might imagine it involves memorising all the constellations, but sometimes the best star patterns to look for aren't constellations at all. An 'asterism' is any pattern of stars that's not one of the official 88 constellations. And one of the easiest asterisms to spot, especially during the northern hemisphere's summer months, is the Summer Triangle.

The Summer Triangle is made up of three bright stars: Vega, Deneb and Altair. Each is in a different constellation: Lyra the harp, Cygnus the swan and Aquila the eagle respectively. The brightness of these stars means that the asterism is visible even in places with light pollution.

The Summer Triangle is visible for most of the year, but in July and August it shines directly overhead at around midnight. June is a good time to see it, too, because it rises above the eastern horizon at around 11pm, so you can use the horizon as a reference. At this time, the sky won't be completely dark, so only the three stars in the triangle will be visible. Later in the night, fainter stars will become visible too (see the diagram above).

Vega is the brightest of the trio, so look first for this star. Then, to the lower left and lower right, you'll find Deneb and Altair respectively. The trickiest thing about identifying the triangle is that it spans quite a large area of sky, but once you've seen it, you'll learn how to recognise it.

If you live somewhere with low light pollution, you can use the Summer Triangle as a map to the Milky Way. Pick a night with little or no moonlight (the few days surrounding the new moon on 21 June), wait until it is darkest (between 12:30am and 1:30am), find the Summer Triangle, and look for a band of light passing through it. You're looking edgewise into the flat disk of stars that makes up our Galaxy. *AB*

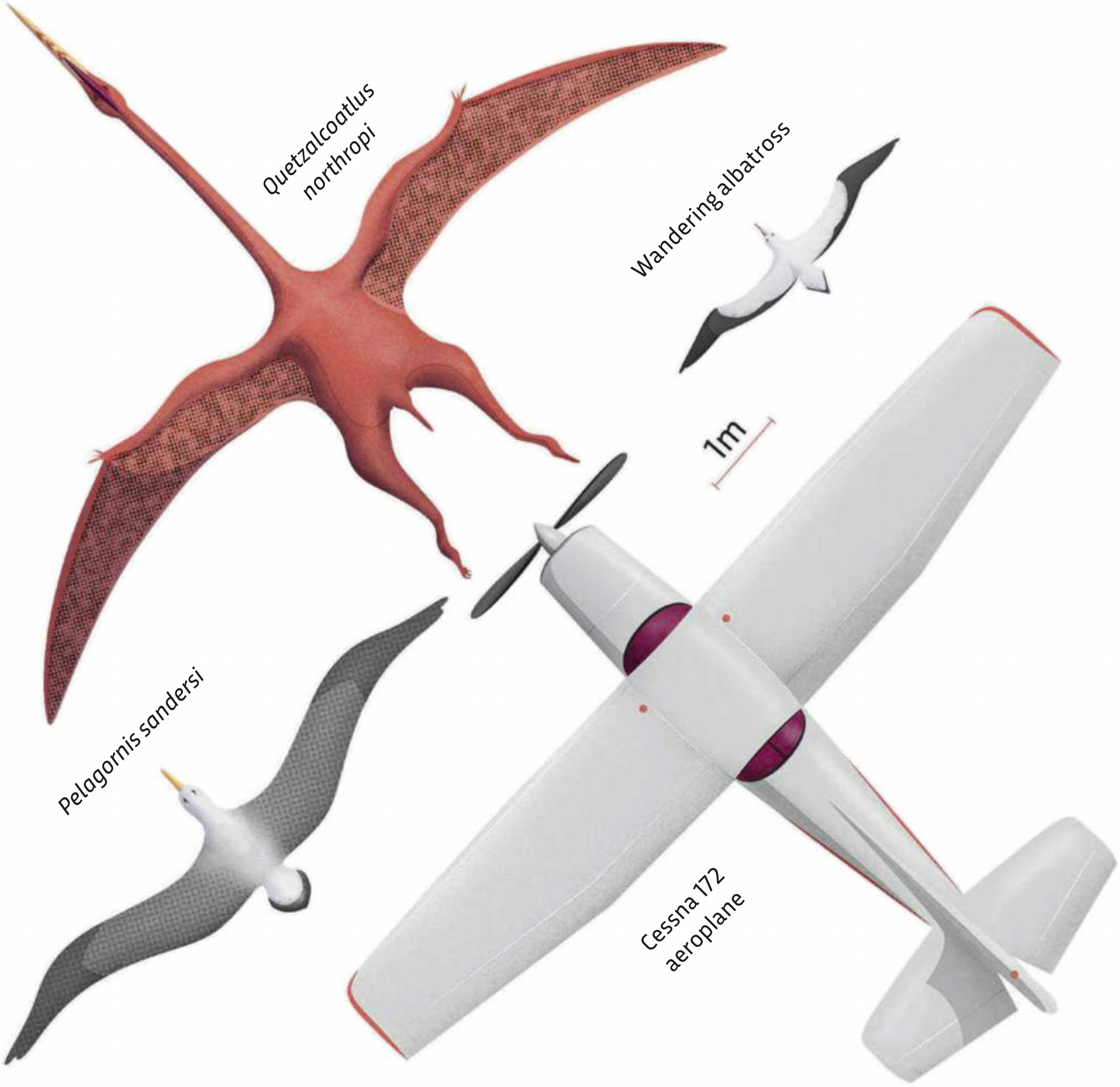
TOP 10

SMARTEST COUNTRIES

(AS MEASURED BY NOBEL LAUREATES PER CAPITA)

1	Faroe Islands	**1 Nobel laureate** (1 per 48,497 people)
2	Saint Lucia	**2** (1 per 90,945 people)
3	Luxembourg	**2** (1 per 303,864)
4	Switzerland	**28** (1 per 304,162)
5	Sweden	**32** (1 per 318,224)
6	Iceland	**1** (1 per 353,574)
7	Austria	**22** (1 per 402,138)
8	Norway	**13** (1 per 408,795)
9	Denmark	**13** (1 per 445,957)
10	United Kingdom	**132** (1 per 503,704)

Note: We've included all six Nobel Prizes (Chemistry, Literature, Peace, Physics, Physiology or Medicine, and Economics). Some laureates are counted twice because the official Nobel website mentions them in relation to two countries. Faroe Islands are included as an autonomous territory within the Kingdom of Denmark. Population stats are for 2018 from **data.worldbank.org**



SAM CROSSLEY, BRADFORD

WHAT'S THE LARGEST FLYING ANIMAL?

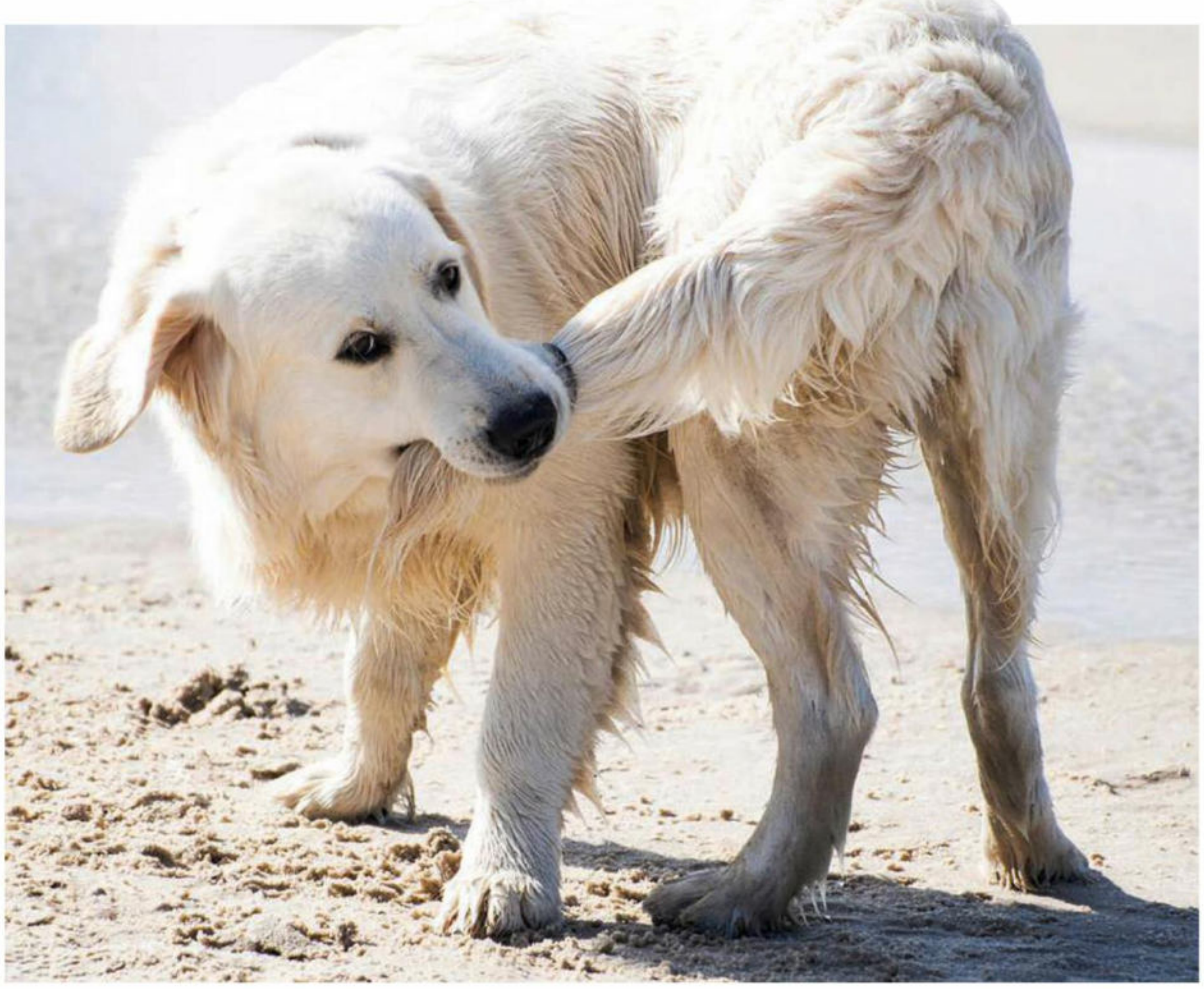
In terms of wingspan, the largest birds are those adapted for soaring, long-distance flight. The wandering albatross is the current record holder, with a maximum recorded wingspan of 3.7 metres, but prehistoric animals were even more impressive. *Pelagornis sandersi*, a bird which lived 25 million years ago, had an estimated wingspan of up to 7.4 metres. Like albatrosses, it probably took to the air by running downhill into a headwind, or launching off cliffs. However, even *P. sandersi* was dwarfed by some of the pterosaurs, those flying reptiles from the time of the dinosaurs. The largest so far discovered is *Quetzalcoatlus northropi*, which may have weighed more than 200kg with a wingspan of 11 metres. That's as wide as a Cessna 172 aeroplane! Computer simulations have shown that *Q. northropi* could soar at 130km/h and stay aloft for up to 10 days. ***LV***

TOBY GRAHAM, SHREWSBURY

WHY DOES LIGHT TRAVEL FASTER THAN SOUND?

According to Einstein's Special Relativity, the speed of light has a unique status: it's a fundamental feature of our Universe, representing the maximum speed at which information can travel from place to place. As such, nothing can match the 300,000km/s achieved by light travelling through a vacuum – least of all sound, which being waves of compression and expansion in a substance doesn't even exist in a vacuum. That said, light can be slowed down by being passed through transparent materials – by around 33 per cent in the case of glass. Even so, it still zooms through glass around 50,000 times faster than sound waves. ***RM***

GETTY IMAGES ILLUSTRATIONS: DANIEL BRIGHT



CHRIS MCMULLON, BARNHAM, WEST SUSSEX

WHY DOES MY DOG GO ROUND IN CIRCLES BEFORE SHE POOS?

A 2015 study in the Czech Republic and Germany reported that dogs tend to poo along the north-south axis of the Earth's magnetic field. This presents the intriguing possibility that the circling behaviour is their way of gauging the orientation of the magnetic field before they get down to business. But this research is controversial, and other researchers have been unable to reproduce the findings. It's more likely that dogs are acting out an ancestral behaviour to flatten the grass and drive away insects before they squat. ***LV***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

WHY DO LOCUSTS SWARM?

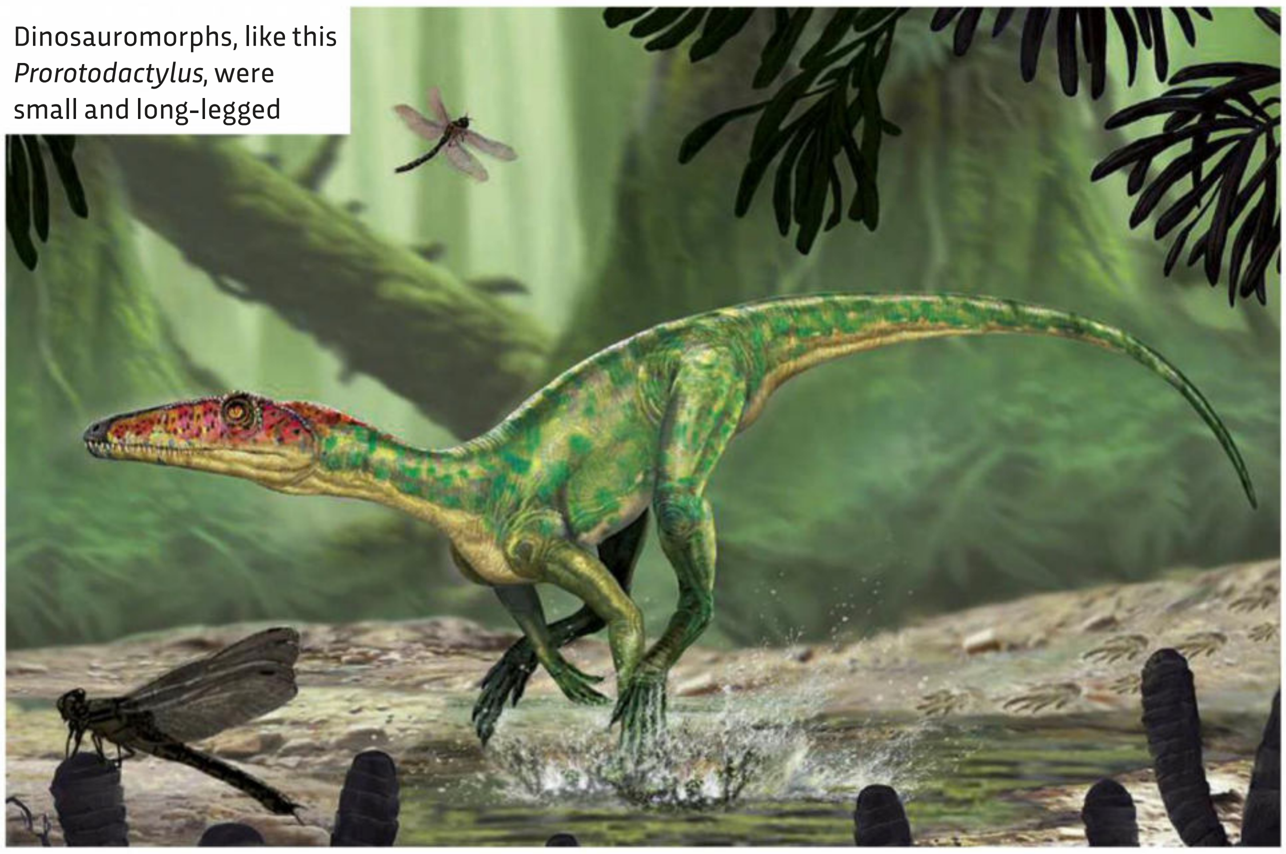
Locusts have caused famine and starvation for as long as humans have been farming. Swarms can appear suddenly, and proceed to decimate crops over huge areas. Since June 2019, one of the worst locust plagues in decades has been devastating parts of East Africa and surrounding regions, consuming up to 1.8 million tonnes of vegetation a day.

Locusts are actually a group of short-horned grasshoppers. They are usually solitary, fairly bland-looking insects, but when conditions are right, they can switch into a 'gregarious' mode, becoming social, multicoloured eating machines that sweep across the landscape in swarms of up to 80 million locusts per square kilometre.

This swarming behaviour is triggered by high rainfall. When there's plenty of lush vegetation for the wingless nymphs (called 'hoppers') to feast on, their numbers swell, and the insects are no longer able to avoid each other. The sight, smell and touch of other locusts causes a flood of serotonin in their brains, which in turn causes genes that control their gregarious phase to switch on, and 'solitary' genes to switch off. The result is a Jekyll-to-Hyde transformation. The gregarious nymphs form into large bands, before taking to the air once they reach their winged, adult stage. As they swarm, any solitary locusts they meet swiftly join the throng.

Why locusts evolved to swarm in the first place is still not fully understood, but a 2008 study suggested that it's because swarms close the gaps between separate patches of locusts, and this makes it harder for predators to move among them and pick the insects off. ***RG***

ALAMY, GETTY IMAGES X2, FRANCO TEMPESTA/ABSOLUTE EXPERT: DINOSAURS/© 2018 NATIONAL GEOGRAPHIC PARTNERS LLC ILLUSTRATION: DANIEL BRIGHT



Dinosauromorphs, like this *Prorotodactylus*, were small and long-legged

ADAM KING, HUDDERSFIELD

WHAT DID DINOSAURS EVOLVE FROM?

Dinosaurs are a type of reptile, and they evolved from another group of reptiles called 'dinosauromorphs' around 250 million years ago. The dinosauromorphs were small and humble animals, and they didn't look anything like *T. rex* or *Brontosaurus*. Instead, they were the size of house cats, walked on all fours, and had long, skinny limbs like a greyhound. The dinosauromorphs weren't at the top of the food chain, but their speed and agility ensured their success. ***SB***

MAEVE BROWN, BRISTOL

HOW CAN I PROTECT MYSELF FROM THE CORONAVIRUS WHEN SHOPPING?

The coronavirus SARS-CoV-2 is spread through respiratory droplets that leave our mouth and nose when we cough, sneeze, or sometimes even talk. These don't usually travel more than one metre, so by keeping two metres from other shoppers, you'll reduce the likelihood of being in the firing line. To make it easier to keep your distance, try to shop during off-peak hours, choose a store that's limiting the number of people who can be inside, and use self-checkout if you can. Keeping your hands clean is the other main thing you can do. If possible, wipe the trolley or basket handles with a disinfectant wipe when you arrive at the store. When you get home, wash your hands or use hand sanitiser before and after unpacking your bags. ***JR***

OLD WIVES' TALES...

EAT A CURRY TO BRING ON LABOUR

Unfortunately for impatient mums-to-be, this one's a myth. It probably has its origins in the fact that curry often has other effects 'down there'. Spicy food is known to irritate the intestines (hence the post-curry diarrhoea that some people experience), and it might also irritate the uterus and in some cases cause small contractions. But there's no evidence that this could bring on labour. Castor oil – a vegetable oil from castor beans – is a more powerful laxative, and some small studies have concluded that the oil can help induce labour. In 2012, researchers in Germany suggested a possible mechanism, finding that an acid in castor oil mimics the effects of hormone-like substances in the body called prostaglandins, which can stimulate contractions in the intestines and uterus. However, the evidence is mixed, and castor oil's laxative effects can cause nausea, diarrhoea and dehydration, so pregnant women are advised to avoid it.

There are a whole host of other foods and drinks that have been said to help bring on labour, including dates, pineapple, raspberry leaf tea and aubergine ('eggplant' in the US). The latter is probably due to the labour-inducing claims made for a famous 'eggplant parmesan' dish at a restaurant near Atlanta, Georgia. But there are no scientifically proven ways to induce labour at home, so pregnant women are best off waiting it out. ***LV***

CURRY SPICE

CRAIG EDWARDS, WOLVERHAMPTON

WHERE DOES SOIL COME FROM?

Soil is a mixture of minerals, organic matter, living organisms, water and air. The minerals (about 50 per cent of soil) are particles of weathered rock, which include tiny grains of clay and silt as well as larger sand particles. The living organisms include fungi, bacteria and insects, and the organic matter incorporates dead plants and microbes, plus other animals in various stages of decomposition. The final product of decomposition is a dark, organic material called humus, which contains relatively high amounts of nitrogen – a nutrient that's vital to plant health.

Initially, soils form from a 'parent material' on the Earth's surface. This could be bedrock that's been eroded, or material that's been transported by glaciers, rivers or wind. Over time, more layers, or 'horizons', are built up. This process takes tens of thousands of years as rocks are slowly weathered and organic matter accumulates. The properties of the soil depend on the local conditions. Sandy areas have gritty soils that drain rapidly; boggy areas have dark, spongy peat; clay-rich areas have sticky soils that crack when dry.

We usually take soil for granted, but it's estimated that a quarter of all species live in or on soil, and we need soil to grow 95 per cent of our food. Soil also plays a wider role in absorbing water (and thus reducing flooding), and locking away carbon. However, soils are under growing pressure from intensive farming and tilling, overharvesting and the use of chemicals. As a result, we lose the equivalent of 30 football pitches of fertile soil every minute. ***AFC***

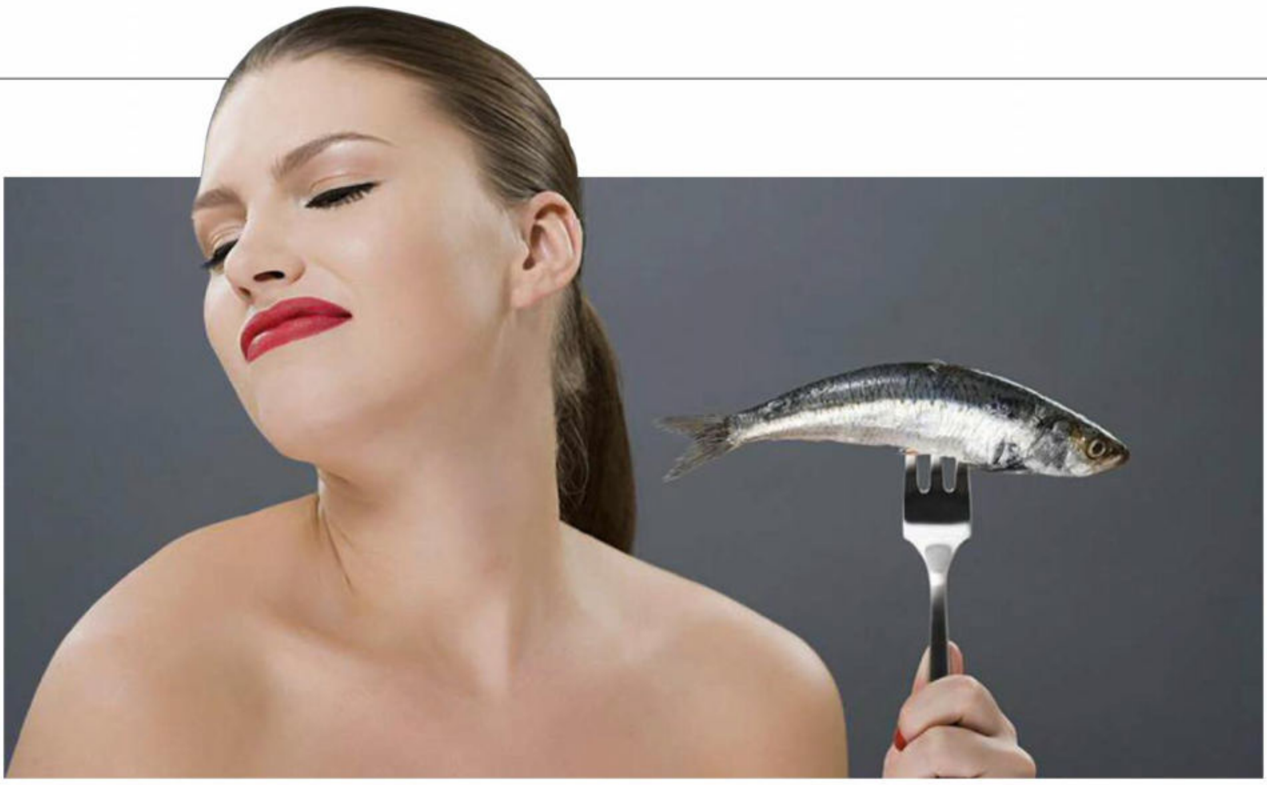
DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

WHY DO I ALWAYS GET AN ENERGY CRASH IN THE AFTERNOON?

Your internal body clock, or 'circadian rhythm', can explain why you feel so sluggish after lunch. The circadian rhythm is controlled by a tiny region at the base of the brain called the suprachiasmatic nucleus (SCN), which makes us feel sleepy in the evening by sending a signal to the body to release the snooze-inducing hormone melatonin, which also lowers our body temperature. However, we also experience a miniature version of this process between around 2pm and 4pm. The reason for this isn't clear, but research suggests that some aspects of our circadian rhythm have a 12-hour cycle, as well as the primary 24-hour one.

The feeling of fatigue can also be intensified by other factors, such as eating a carb-heavy lunch, not getting enough sleep the previous night, or being dehydrated. If you're really struggling, a post-lunch nap isn't such a bad idea. Studies have shown that a 20- to 30-minute snooze can boost alertness, attention and mood, and there are even companies who have invested in workplace sleep pods for their staff. That's not feasible for everyone, though. So another option is to go for a lunchtime stroll. Light has a big effect on our circadian rhythm, helping to calibrate the SCN, so a good dose of sunshine can be just as effective as a nap at setting you up for the afternoon. ***SO***



BRENDAN FALVEY

IS IT POSSIBLE TO HAVE ZERO SENSE OF SMELL?

The medical term for this is 'anosmia'. People can be born with no sense of smell, due to genetic factors, but most lose it later in life, sometimes permanently. Anosmia has many causes, including head injury, dementia, nasal polyps, and even snake bites. But the most common cause, accounting for up to 40 per cent of cases, is a viral infection. Indeed, one reported symptom of the coronavirus disease COVID-19 is a loss of smell. It's not yet known what causes this, but I experienced it for myself when I had a mild case of COVID-19 earlier this year. My sense of smell gradually returned, but even after three weeks, I still couldn't smell coffee. ***LV***

NATALIE WEAVER (AGED 11)

WHY IS THE SKY BLUE?

It's often thought it's because of light reflected back into the sky from the blue sea. In fact, it's the result of sunlight being scattered when it strikes the air molecules in the atmosphere. Sunlight is made up of – literally – all the colours of the rainbow, and the complex physics of how light interacts with molecules means shorter-wavelength blue light is more strongly scattered than red light. As a result, it is blue-coloured light that ends up spread most widely across the sky, dominating its appearance. ***RM***

QUESTION OF THE MONTH

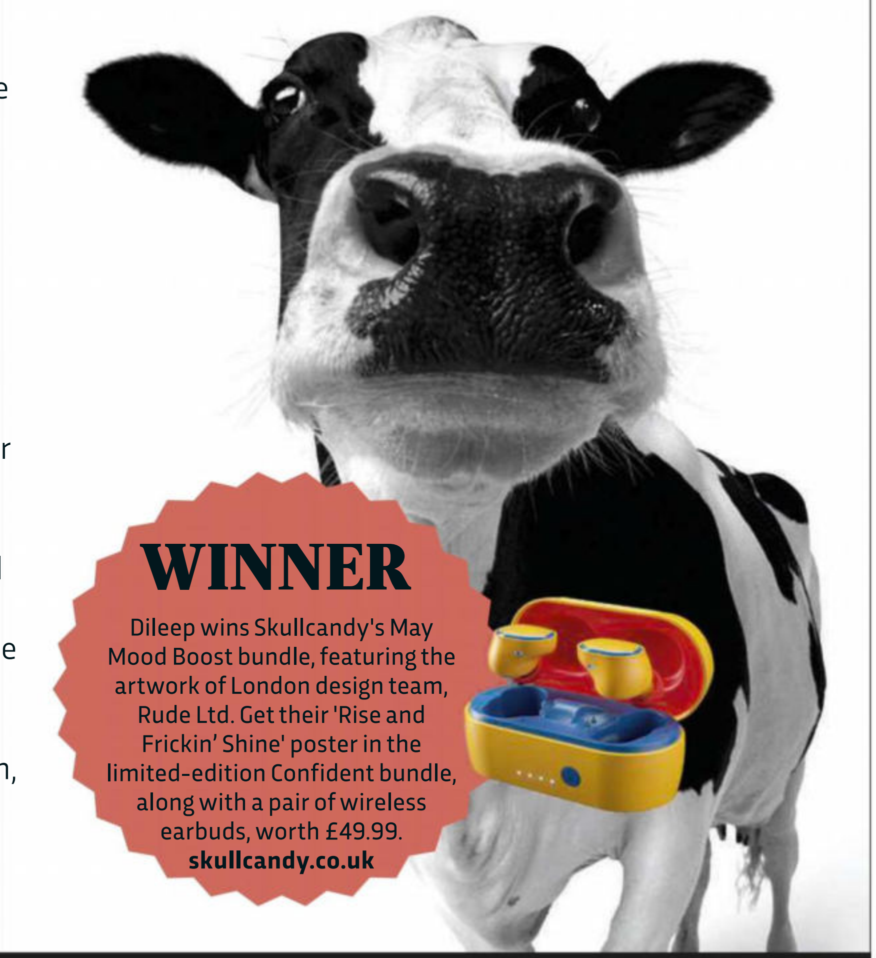
DILEEP BAGNALL, LANCASHIRE

WHAT ARE COWS COMMUNICATING WHEN THEY MOO?

Old MacDonald had a farm with an 'oink oink' here and a 'moo moo' there, but we'd be foolish to think that these vocalisations have no significance. Cows are smart, social animals. They have a rich repertoire of communication that includes moos, grunts, bellows and even non-verbal signals such as tail position.

In 2014, researchers at the University of Nottingham and Queen Mary University of London decided to delve a little deeper by recording 10 months' worth of moos and then using computer analysis to look for patterns. Just as our voices differ, the researchers found that each mother and calf have their own individual call. This is thought to help them identify each other in a herd. The researchers could also tell a calf's age by the sound of its call. Meanwhile, mother cows produce two different maternal calls: a low-pitched moo when they are close to their calves, and a louder, higher-pitched moo when they are separated from their calves, or just before nursing. Calves, in return, make a different call when they are separated from their mother and/or want to suckle.

Of course, this is just the tip of the iceberg. Ask any farmer and they will tell you that cows 'talk', not just to each other, but also to those who care for them. Cows moo when they are hungry or stressed. They moo as a warning and they moo in anticipation, if, for example, the farmer is approaching with a big bale of delicious hay. ***HP***



WINNER

Dileep wins Skullcandy's May Mood Boost bundle, featuring the artwork of London design team, Rude Ltd. Get their 'Rise and Frickin' Shine' poster in the limited-edition Confident bundle, along with a pair of wireless earbuds, worth £49.99. **skullcandy.co.uk**

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THE EXPLAINER

HOW DO I START STARGAZING AT HOME?

Being stuck at home could provide the perfect opportunity to get to know the night sky, and you don't even need a telescope. Here are nine tips on stargazing with the naked eye, courtesy of *BBC Sky At Night* magazine

DRESS FOR THE OCCASION

Before you even look at the sky, take a look at yourself in the mirror. Are you dressed properly? You're going to be outside for at least an hour, hopefully longer, and it can get cold even on summer nights. So dress appropriately, with a warm jacket, thick socks, and gloves, scarf and a hat. Basically, you want to look like one of the rosy-cheeked children playing happily in the winter snow from a vintage Ladybird book.

PREPARE YOUR SITE

Find a spot in your garden where you can see as much of the night sky as possible, away from other houses, tall buildings and trees. If you don't have a garden, you can also stargaze from a balcony or front step, or through a skylight. If you're going to be outside for a while, take a chair – a reclining chair will allow you to look upwards without straining your neck. Turn off all your outdoor lights and, if you can, get your neighbours to do the same. If you don't have somewhere to stargaze, or if there's a lot of light pollution, then you might need to find another site (lockdown restrictions permitting!). Head to a dark spot in the countryside, or just walk around the corner to your local park or playing field.

ADJUST YOUR EYES

Once you're comfy, let your eyes adjust to the darkness. Astronomers call this process 'dark adaptation', and it takes about half an hour. Don't browse on your phone while you wait (its bright screen will ruin your night vision). If you need some light, use a red light torch, or a red bicycle light.

SEE THE STARS

Once your eyes have adjusted, you won't believe how many more stars you can see. You might be able to notice subtle differences in the stars' colours, which depend on their temperature: the hottest stars are more of a bluish colour, while cooler stars have a yellow, orange or red tint.

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SPOT A PLANET

If you see a bright 'star' that isn't twinkling, it's almost certainly a planet. Why do stars twinkle, and planets don't? A star is so far away that its pinprick of light arrives in a narrow beam, which is easily distorted as it passes through our atmosphere (we see this as twinkling). Planets are much closer, and their light (reflected from the Sun) comes to us in a thicker beam, which isn't so easily distorted. In June, there'll be chance to see all five 'naked eye' planets (Mercury, Venus, Mars, Saturn and Jupiter). For tips on how to spot them, visit **skyatnight-magazine.com/advice/skills/how-see-planets-night-sky-june**

Venus and Mercury over the Lake District

MARVEL AT THE MOON

Go outside on a cloudless night and reacquaint yourself with our closest celestial neighbour. Impact craters appear as bright patches on the Moon's surface, while the dark regions, known as lunar maria, are vast plains of solidified lava. The Moon's features cast more impressive shadows, and are hence easier to pick out, when they're close to the 'terminator' – the dividing line between the Moon's dark and illuminated portions. So a crescent or a gibbous moon can be just as interesting as a full moon, especially when seen through binoculars.

LOOK FOR PATTERNS

The stars can be joined up to form patterns. You might recognise one straight away: the saucepan-shaped Plough, which is visible all year round. The Plough is an 'asterism' – a star pattern that's not one of the official constellations. It forms part of the constellation Ursa Major (the Great Bear). Another asterism to look out for in June is the Summer Triangle (see p80).

Very few of the 88 constellations look like the person, animal or object they represent, so you'll need to use some imagination! If you return to your observing site in another season, you'll notice that the constellations you can see have changed. This is because the Earth is in a different position in space as it orbits the Sun, and it's why it takes a year to properly get to know the sky, not just one night.

SAGITTARIUS

DOWNLOAD AN APP

Stargazing apps can be a great way to familiarise yourself with the positions of the stars and planets. You'll need to make sure you turn your screen brightness right down to keep your night vision, or turn on the app's red screen filter if it has one. Some good, free-to-download apps include *Stellarium Mobile Free*, *SkyView Lite* and *Star Walk 2 Free*.

SPOT A METEOR

As you're gazing skywards, you might be lucky enough to see a meteor dash across the sky: a shooting star! These are tiny grains of space dust burning up in the atmosphere. Larger, brighter meteors, called fireballs, can survive their trip through the atmosphere and drop meteorites on the ground. Your best chance of seeing a shooting star is during a meteor shower, when the Earth passes through the dusty trail left by a comet. One of the best annual showers is the Perseids, which peaks this year around 11-13 August.

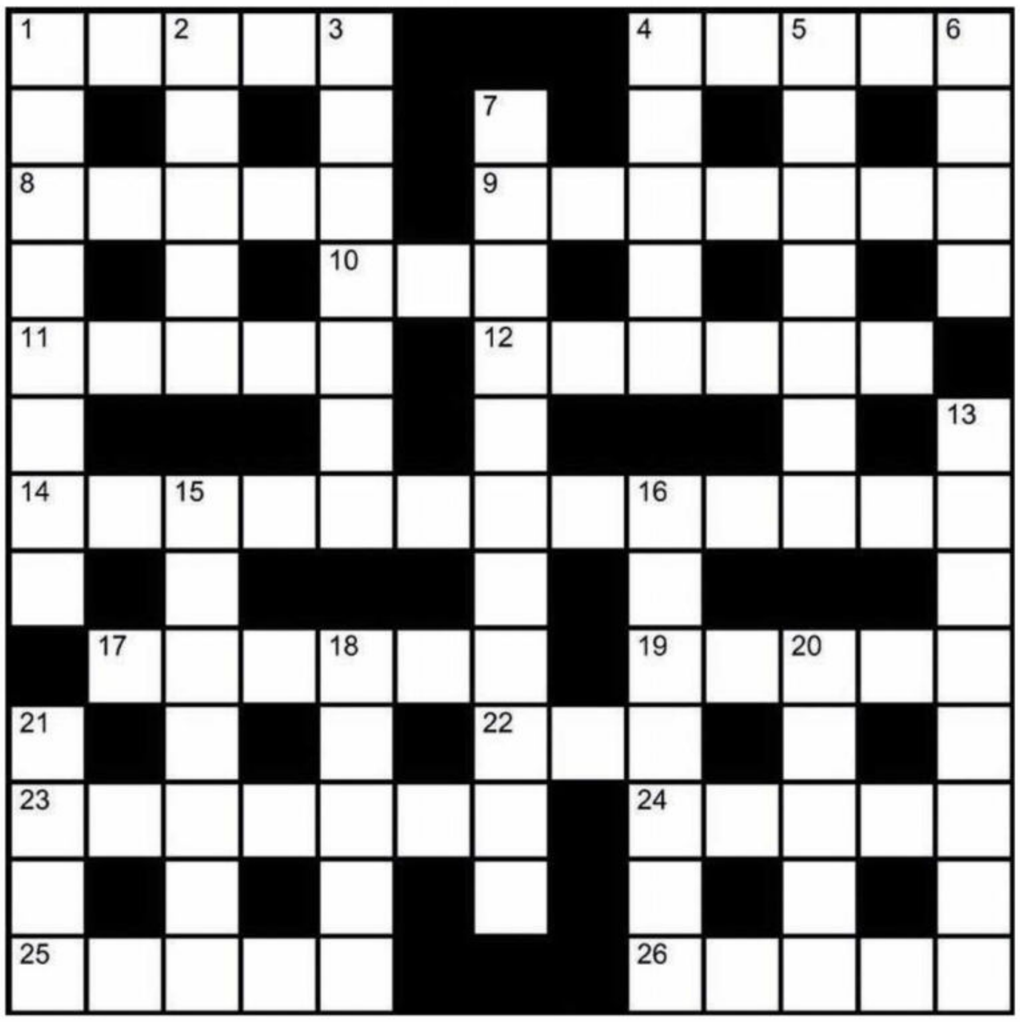
DISCOVER MORE

BBC
Sky at Night
SUMMER SKIES

For more stargazing advice for beginners, head to ***skyatnightmagazine.com/tag/astronomyforbeginners/***

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Readily available where hot and cold can be found (2,3)
4 Doctor pursues firm oxygen pairing (5)
8 Train decathlete, initially by stream (5)
9 Almost commend a liberal officer (7)
10 Feel modest about growth (3)
11 Contributing element, removing first performer (5)
12 Regular figure is round, left unfinished (6)
14 Pop has it as a greenhouse gas (6,7)
17 Points to raise about losing a TV programme (6)
19 Sketch doctor at the back (5)
22 Heard first person getting an organ (3)
23 Greeting endlessly, ruined number (7)
24 Sap is from sycamores indeed (5)
25 Her and my form for a poem (5)
26 Surrender produce (5)

DOWN

1 Guns, alternatively, new in routine (8)
2 Colour includes a suggestion (5)
3 Friend confused Rome and another capital (7)
4 Some jewellery arrived on the second of November (5)
5 Macron upsetting Italy's top inventor (7)
6 Capital of Czechoslovakia (4)
7 Mere bandits wandering around wasteland (5,6)
13 Heading isn't fixed in deed (8)
15 Astronaut's return is naive, not starting attempt (2-5)
16 Methodically arranged for hospital worker (7)
18 Fireplace showing one front part removed (5)
20 I will be heard in the passage (5)
21 Less intelligent, first couple leaving jetty (4)

ANSWERS For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

IS IT BRIE YOU'RE LOOKING FOR?

The science of cheese and why your brain loves it.

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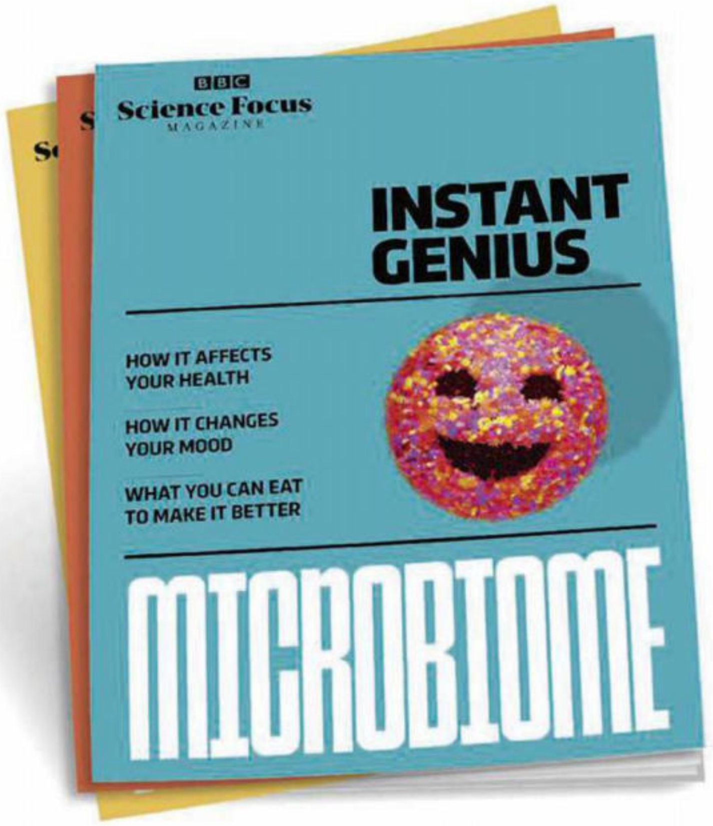

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A SCIENTIST'S GUIDE TO LIFE

HOW TO BAKE BREAD BRILLIANTLY

WITH LIFE STILL IN LOCKDOWN, MORE PEOPLE THAN EVER ARE TURNING TO BAKING. HERE'S HOW TO BAKE THE PERFECT LOAF, WITH NUTRITION SCIENTIST **HALEH MORAVEJ**

TREAT BREAD-MAKING LIKE A SCIENCE EXPERIMENT

Baking is a science, so don't guesstimate. Make sure, for example, that the water you add is at the right temperature. Too hot or too cold and the yeast won't work. If it says to add a certain amount of yeast or salt, ensure you do.

STRONG FLOUR IS BEST

Strong flour has the highest amount of protein in it. It contains glutenin and gliadin, which combine to make gluten when water is added. If you use flour with a low protein content, the bread is likely to be heavy and dense.

KNEADING IS IMPORTANT

As the dough is stretched, it helps to line up the messy strands of gluten. It's a bit like combing the tangles from your hair! This makes the bread stronger.

KNOW YOUR YEAST

Yeast is a single-celled organism. Bakers use *Saccharomyces cerevisiae*, which means 'sugar-eating fungi'. As it eats sugar, it produces carbon dioxide, which helps make the bread light and bubbly. This is fermentation. Connoisseurs of bread may prefer live yeast, but it only survives for a few weeks. Dry yeast has a longer shelf life because it's dehydrated. I recommend another type of yeast, called instant yeast, which is even more dehydrated. It rehydrates and gets to work on the bread quickly. It lasts longer too.

DON'T FORGET THE SALT

Salt is hygroscopic, so it attracts water. When it's mixed into a dough that contains yeast, it absorbs moisture and helps to control the fermentation.

THERE IS CHEMISTRY BEHIND A CRUSTY TOP

The much sought after 'brown crusty top' is caused by the Maillard reaction. This is a chemical reaction between amino acids and sugars that requires moisture and heat. One option is to spray the dough with water a few times while it is cooking. Another is to fill a baking tray with ice cubes and place it in the bottom of your preheated oven before baking your bread, to create steam.

GO GLUTEN-FREE

Gluten strands bind things together. Xanthan gum is a gluten-free binding alternative that can be added to many gluten-free flours, but I find that the bread it produces is too dense. Don't bother with special gluten-free flours. Go for naturally gluten-free grains like rice, chickpea, soy, and cornflour. They're straightforward to bake with.

NEXT-LEVEL BREAD MAKING

For something trickier, try sourdough. Sourdough bakers keep starter cultures of bacteria and yeast which they feed and manage. It's a bit like keeping a pet! **SF**

HALEH MORAVEJ
(@HalehMoravej)
Haleh is senior lecturer in nutritional sciences at Manchester Metropolitan University.
Interviewed by Helen Pilcher.

NEED TO KNOW...

1

Don't guesstimate – baking is a science!

2

Proving cupboards are overrated. Just cover your dough with a tea towel and prove at room temperature.

3

Use instant yeast – it has a long shelf life and works well.

ILLUSTRATION: CATHAL DUANE

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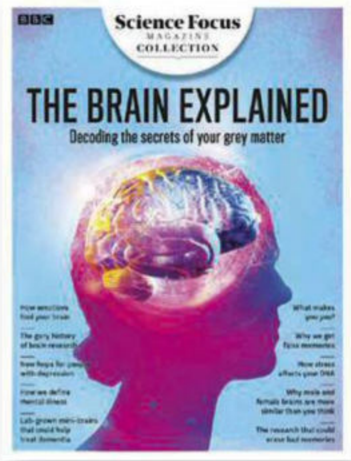
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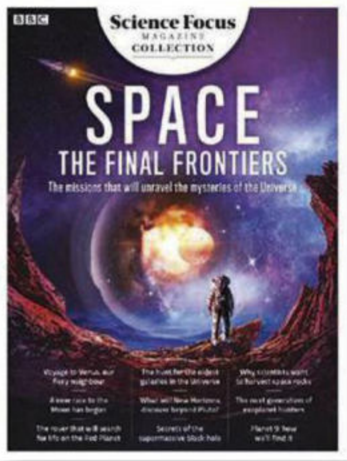
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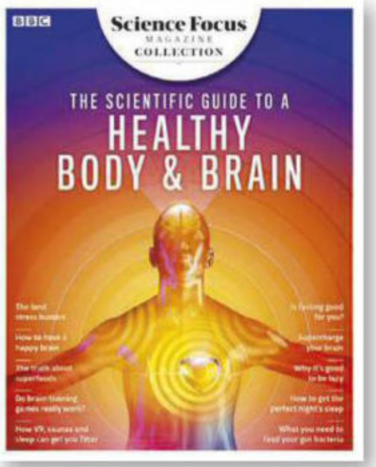
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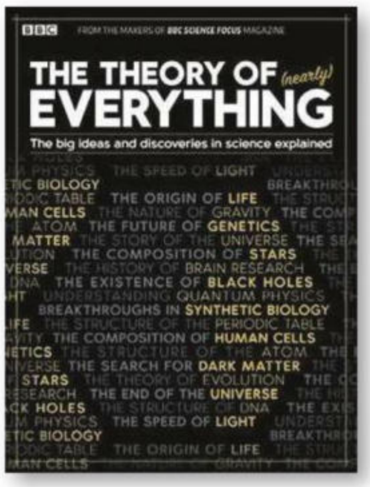
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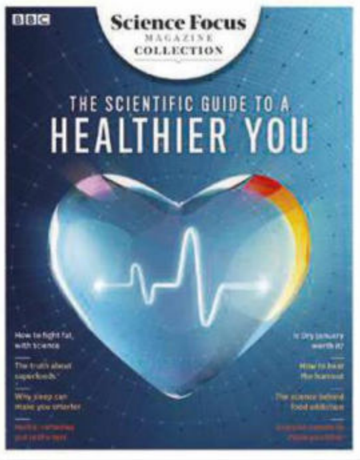
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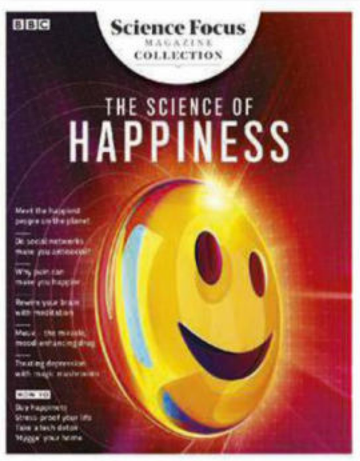
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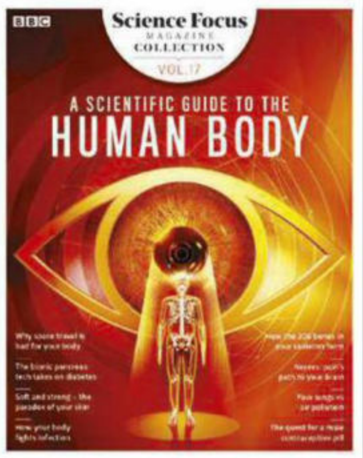
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